What every programmer absolutely, positively needs to know about encodings and character sets to work with text

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If you are dealing with text in a computer, you need to know about encodings. Period. Yes, even if you are just sending emails. Even if you are just *receiving* emails. You don't need to understand every last detail, but you must at least know what this whole "encoding" thing is about. And the good news first: while the topic *can* get messy and confusing, the basic idea is really, really simple.

This article is about encodings and character sets. An article by Joel Spolsky entitled The Absolute Minimum Every Software Developer Absolutely, Positively Must Know About Unicode and Character Sets (No Excuses!) is a nice introduction to the topic and I greatly enjoy reading it every once in a while. I hesitate to refer people to it who have trouble understanding encoding problems though since, while entertaining, it is pretty light on actual technical details. I hope this article can shed some more light on what exactly an encoding is and just why all your text screws up when you least need it. This article is aimed at developers (with a focus on PHP), but any computer user should be able to benefit from it.

Getting the basics straight

Everybody is aware of this at some level, but somehow this knowledge seems to suddenly disappear in a discussion about text, so let's get it out first: A computer cannot store "letters", "numbers", "pictures" or anything else. The only thing it can store and work with are *bits*. A bit can only have two values: `yes` or `no`, `true` or `false`, `1` or `0` or whatever else you want to call these two values. Since a computer works with electricity, an "actual" bit is a blip of electricity that either is or isn't there. For humans, this is usually represented using `1` and `0` and I'll stick with this convention throughout this article.

To use bits to represent anything at all besides bits, we need rules. We need to convert a sequence of bits into something like letters, numbers and pictures using an *encoding scheme*, or *encoding* for short. Like this:

```
01100010 01101001 01110100 01110011
b        i        t        s
```

In this *encoding*, `01100010` stands for the letter "b", `01101001` for the letter "i", `01110100` stands for "t" and `01110011` for "s". A certain sequence of bits stands for a letter and a letter stands for a certain sequence of bits. If you can keep this in your head for 26 letters or are really fast with looking stuff up in a table, you could read bits like a book.

The above encoding scheme happens to be ASCII. A string of `1`s and `0`s is broken down into parts of eight bit each (a *byte* for short). The ASCII encoding specifies a table translating bytes into human readable letters. Here's a short excerpt of that table:

bits	character
`01000001`	A
`01000010`	B
`01000011`	C
`01000100`	D
`01000101`	E
`01000110`	F

There are 95 human readable characters specified in the ASCII table, including the letters A through Z both in upper and lower case, the numbers 0 through 9, a handful of punctuation marks and characters like the dollar symbol, the ampersand and a few others. It also includes 33 values for things like space, line feed, tab, backspace and so on. These are not *printable* per se, but still visible in some form and useful to humans directly. A number of values are only useful to a computer, like codes to signify the start or end of a text. In total there are 128 characters defined in the ASCII encoding, which is a nice round number (for people dealing with computers), since it uses all possible combinations of 7 bits (`0000000`, `0000001`, `0000010` through `1111111`).[1]

And there you have it, the way to represent human-readable text using only `1`s and `0`s.

> ```
> 01001000 01100101 01101100 01101100 01101111 00100000
>   01010111 01101111 01110010 01101100 01100100
> ```
>
> "Hello World"

Important terms

To *encode* something in ASCII, follow the table from right to left, substituting letters for bits. To decode a string of bits into human readable characters, follow the table from left to right, substituting bits for letters.

> **encode** |enˈkōd|
> verb [with obj.]
> *convert into a coded form*
>
> **code** |kōd|
> noun
> *a system of words, letters, figures, or other symbols substituted for other words, letters, etc.*

To *encode* means to use something to represent something else. An *encoding* is the set of

rules with which to convert something from one representation to another.

Other terms which deserve clarification in this context:

character set, charset
The set of characters that can be encoded. "The ASCII encoding encompasses a character set of 128 characters." Essentially synonymous to "encoding".

code page
A "page" of codes that map a character to a number or bit sequence. A.k.a. "the table". Essentially synonymous to "encoding".

string
A string is a bunch of items strung together. A bit string is a bunch of bits, like `01010011`. A character string is a bunch of characters, `like this`. Synonymous to "sequence".

Binary, octal, decimal, hex

There are many ways to write numbers. 10011111 in binary is 237 in octal is 159 in decimal is 9F in hexadecimal. They all represent the same value, but hexadecimal is shorter and easier to read than binary. I will stick with binary throughout this article to get the point across better and spare the reader one layer of abstraction. Do not be alarmed to see character codes referred to in other notations elsewhere, it's all the same thing.

Excusez-moi?

Now that we know what we're talking about, let's just say it: 95 characters really isn't a lot when it comes to languages. It covers the basics of English, but what about writing a risqué letter in French? A Straßenübergangsänderungsgesetz in German? An invitation to a smörgåsbord in Swedish? Well, you couldn't. Not in ASCII. There's no specification on how to represent any of the letters é, ß, ü, ä, ö or å in ASCII, so you can't use them.

"But look at it," the Europeans said, "in a common computer with 8 bits to the byte, ASCII is wasting an entire bit which is always set to `0`! We can use that bit to squeeze a whole 'nother 128 values into that table!" And so they did. But even so, there are more than 128 ways to stroke, slice, slash and dot a vowel. Not all variations of letters and squiggles used in all European languages can be represented in the same table with a maximum of 256 values. So what the world ended up with is a wealth of encoding schemes, standards, de-facto standards and half-standards that all cover a different subset of characters. Somebody needed to write a document about Swedish in Czech, found that no encoding covered both languages and invented one. Or so I imagine it went countless times over.

And not to forget about Russian, Hindi, Arabic, Hebrew, Korean and all the other languages currently in active use on this planet. Not to mention the ones not in use anymore. Once you have solved the problem of how to write mixed language documents in all of these languages, try yourself on Chinese. Or Japanese. Both contain tens of thousands of characters. You have 256 possible values to a byte consisting of 8 bit. Go!

Multi-byte encodings

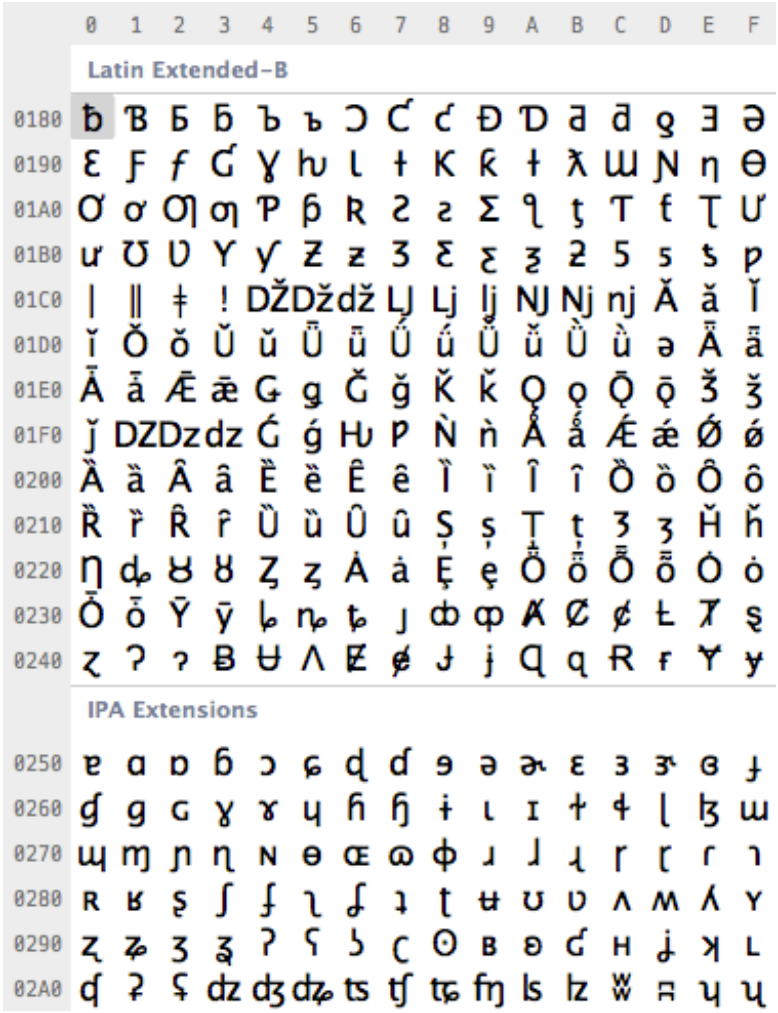
To create a table that maps characters to letters for a language that uses more than 256 characters, one byte simply isn't enough. Using two bytes (16 bits), it's possible to encode 65,536 distinct values. BIG-5 is such a *double-byte encoding*. Instead of breaking a string of bits into blocks of eight, it breaks it into blocks of 16 and has a big (I mean, BIG) table that specifies which character each combination of bits maps to. BIG-5 in its basic form covers mostly Traditional Chinese characters. GB18030 is another encoding which essentially does the same thing, but includes both Traditional and Simplified Chinese characters. And before you ask, yes, there are encodings which cover only Simplified Chinese. Can't just have one encoding now, can we?

Here a small excerpt from the GB18030 table:

bits	character
`10000001 01000000`	ㄎ
`10000001 01000001`	ㄏ
`10000001 01000010`	ㄐ
`10000001 01000011`	ㄑ
`10000001 01000100`	ㄒ

GB18030 covers quite a range of characters (including a large part of latin characters), but in the end is yet another specialized encoding format among many.

Unicode to the confusion



Finally somebody had enough of the mess and set out to ~~forge a ring to bind them all~~ create one encoding standard to unify all encoding standards. This standard is Unicode. It basically defines a ginormous table of 1,114,112 code points that can be used for all sorts of letters and symbols. That's plenty to encode all European, Middle-Eastern, Far-Eastern, Southern, Northern, Western, pre-historian and future characters mankind knows about.[2] Using Unicode, you can write a document containing virtually any language using any character you can type into a computer. This was either impossible or very very hard to get right before Unicode came along. There's even an unofficial section for Klingon in Unicode. Indeed, Unicode is big enough to allow for *unofficial*, private-use areas.

So, how many bits does Unicode use to encode all these characters? *None.* Because Unicode is not an encoding.

Confused? Many people seem to be. *Unicode* first and foremost defines a table of *code points* for characters. That's a fancy way of saying *"65 stands for A, 66 stands for B and 9,731 stands for ☃"* (seriously, it does). How these code points are actually *encoded into bits* is a different topic. To represent 1,114,112 different values, two bytes aren't enough. Three bytes are, but three bytes are often awkward to work with, so four bytes would be the comfortable minimum. But, unless you're actually using Chinese or some of the other characters with big numbers that take a lot of bits to encode, you're never going to use a huge chunk of those four bytes. If

the letter "A" was always encoded to `00000000 00000000 00000000 01000001`, "B" always to `00000000 00000000 00000000 01000010` and so on, any document would bloat to four times the necessary size.

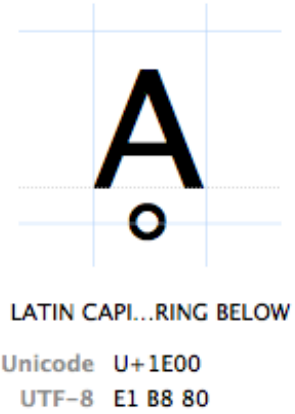
To optimize this, there are several ways to encode Unicode code points into bits. UTF-32 is such an encoding that encodes all Unicode code points using 32 bits. That is, four bytes per character. It's very simple, but often wastes a lot of space. UTF-16 and UTF-8 are *variable-length encodings*. If a character can be represented using a single byte (because its code point is a very small number), UTF-8 will encode it with a single byte. If it requires two bytes, it will use two bytes and so on. It has elaborate ways to use the highest bits in a byte to signal how many bytes a character consists of. This can save space, but may also waste space if these signal bits need to be used often. UTF-16 is in the middle, using at least two bytes, growing to up to four bytes as necessary.

character	encoding	bits
A	UTF-8	`01000001`
A	UTF-16	`00000000 01000001`
A	UTF-32	`00000000 00000000 00000000 01000001`
あ	UTF-8	`11100011 10000001 10000010`
あ	UTF-16	`00110000 01000010`
あ	UTF-32	`00000000 00000000 00110000 01000010`

And that's all there is to it. Unicode is a large table mapping characters to numbers and the different UTF encodings specify how these numbers are encoded as bits. Overall, Unicode is *yet another encoding scheme*. There's nothing special about it, it's just trying to cover everything while still being efficient. And that's A Good Thing.™

Code points

Characters are referred to by their "Unicode code point". Unicode code points are written in hexadecimal (to keep the numbers shorter), preceded by a "U+" (that's just what they do, it has no other meaning than "this is a Unicode code point"). The character Ḁ has the Unicode code point U+1E00. In other (decimal) words, it is the 7680th character of the Unicode table. It is officially called "LATIN CAPITAL LETTER A WITH RING BELOW".



TL;DR

A summary of all the above: Any character can be encoded in many different bit sequences

and any particular bit sequence can represent many different characters, depending on which encoding is used to read or write them. The reason is simply because different encodings use different numbers of bits per characters and different values to represent different characters.

bits	encoding	characters
`11000100 01000010`	Windows Latin 1	ÄB
`11000100 01000010`	Mac Roman	ƒB
`11000100 01000010`	GB18030	腂

characters	encoding	bits
Føö	Windows Latin 1	`01000110 11111000 11110110`
Føö	Mac Roman	`01000110 10111111 10011010`
Føö	UTF-8	`01000110 11000011 10111000 11000011 10110110`

Misconceptions, confusions and problems

Having said all that, we come to the actual problems experienced by many users and programmers every day, how those problems relate to all of the above and what their solution is. The biggest problem of all is:

Why in god's name are my characters garbled?!

```
ÉGÉìÉRÅ[ÉfÉBÉìÉOÇÕìÔÇµÇ≠Ç»Ç¢
```

If you open a document and it looks like this, there's one and only one reason for it: Your text editor, browser, word processor or whatever else that's trying to read the document is assuming the wrong encoding. That's all. The document is not broken (well, unless it is, see below), there's no magic you need to perform, you simply need to select the right encoding to display the document.

The hypothetical document above contains this sequence of bits:

```
10000011 01000111 10000011 10010011 10000011 01010010 10000001 01011011
10000011 01100110 10000011 01000010 10000011 10010011 10000011 01001111
10000010 11001101 10010011 11101111 10000010 10110101 10000010 10101101
10000010 11001000 10000010 10100010
```

Now, quick, what encoding is that? If you just shrugged, you'd be correct. Who knows, right?

Well, let's try to interpret this as ASCII. Hmm, most of these bytes start [3] with a `1` bit. If you remember correctly, ASCII doesn't use that bit. So it's not ASCII. What about UTF-8? Hmm, no, most of these sequences are not valid UTF-8.[4] So UTF-8 is out, too. Let's try "Mac Roman" (yet another encoding scheme for them Europeans). Hey, all those bytes are valid in Mac Roman.

`10000011` maps to "É", `01000111` to "G" and so on. If you read this bit sequence using the Mac Roman encoding, the result is "ÉGÉìÉRÅ[ÉfÉBÉìÉOÇÕìÔÇµÇ≠Ç»Çç". That looks like a valid string, no? Yes? Maybe? Well, how's the computer to know? Maybe somebody meant to write "ÉGÉìÉRÅ[ÉfÉBÉìÉOÇÕìÔÇµÇ≠Ç»Çç". For all I know that could be a DNA sequence.[5] Unless you have a better suggestion, let's declare this to be a DNA sequence, say this document was encoded in Mac Roman and call it a day.

Of course, that unfortunately is complete nonsense. The correct answer is that this text is encoded in the Japanese Shift-JIS encoding and was supposed to read "エンコーディングは難しくない". Well, who'd've thunk?

The *primary* cause of garbled text is: Somebody is trying to read a byte sequence using the wrong encoding. The computer always needs to be told what encoding some text is in. Otherwise it can't know. There are different ways how different kinds of documents can specify what encoding they're in and these ways should be used. A raw bit sequence is always a mystery box and could mean anything.

Most browsers allow the selection of a different encoding in the View menu under the menu option "Text Encoding", which causes the browser to reinterpret the current page using the selected encoding. Other programs may offer something like "Reopen using encoding…" in the File menu, or possibly an "Import…" option which allows the user to manually select an encoding.

My document doesn't make sense in any encoding!

If a sequence of bits doesn't make sense (to a human) in any encoding, the document has mostly likely been converted incorrectly at some point. Say we took the above text "ÉGÉìÉRÅ[ÉfÉBÉìÉOÇÕìÔÇµÇ≠Ç»Çç" because we didn't know any better and saved it as UTF-8. The text editor assumed it correctly read a Mac Roman encoded text and you now want to save this text in a different encoding. All of these characters are valid Unicode characters after all. That is to say, there's a code point in Unicode that can represent "É", one that can represent "G" and so on. So we can happily save this text as UTF-8:

```
11000011 10001001 01000111 11000011 10001001 11000011 10101100 11000011
10001001 01010010 11000011 10000101 01011011 11000011 10001001 01100110
11000011 10001001 01000010 11000011 10001001 11000011 10101100 11000011
10001001 01001111 11000011 10000111 11000011 10010101 11000011 10101100
11000011 10010100 11000011 10000111 11000010 10110101 11000011 10000111
11100010 10001001 10100000 11000011 10000111 11000010 10111011 11000011
10000111 11000010 10100010
```

This is now the UTF-8 bit sequence representing the text "ÉGÉìÉRÅ[ÉfÉBÉìÉOÇÕìÔÇµÇ≠Ç»Çç". This bit sequence has absolutely nothing to do with our original document. Whatever encoding we try to open it in, we won't ever get the text "エンコーディングは難しくない" from it. It is completely lost. It would be possible to recover the original text from it if we knew that a Shift-JIS document was misinterpreted as Mac Roman and then accidentally saved as UTF-8 and reversed this chain of missteps. But that would be a lucky fluke.

Many times certain bit sequences are invalid in a particular encoding. If we tried to open the original document using ASCII, some bytes would be valid in ASCII and map to a real character and others wouldn't. The program you're opening it with may decide to silently discard any bytes that aren't valid in the chosen encoding, or possibly replace them with `?`. There's also the "Unicode replacement character" `�` (U+FFFD) which a program may decide to insert for any character it couldn't decode correctly when trying to handle Unicode. If a document is saved with some characters gone or replaced, then those characters are *really* gone for good with no way to reverse-engineer them.

If a document has been misinterpreted and converted to a different encoding, it's broken. Trying to "repair" it may or may not be successful, usually it isn't. Any manual bit-shifting or other encoding voodoo is mostly that, voodoo. It's trying to fix the symptoms after the patient has already died.

So how to handle encodings correctly?

It's really simple: *Know* what encoding a certain piece of text, that is, a certain byte sequence, is in, then interpret it with that encoding. That's all you need to do. If you're writing an app that allows the user to input some text, specify what encoding you accept from the user. For any sort of text field, the programmer can usually decide its encoding. For any sort of file a user may upload or import into a program, there needs to be a specification what encoding that file should be in. Alternatively, the user needs some way to tell the program what encoding the file is in. This information may be part of the file format itself, or it may be a selection the user has make (not that most users would usually know, unless they have read this article).

If you need to convert from one encoding to another, do so cleanly using tools that are specialized for that. Converting between encodings is the tedious task of comparing two code pages and deciding that character 152 in encoding A is the same as character 4122 in encoding B, then changing the bits accordingly. This particular wheel does not need reinventing and any mainstream programming language includes some way of converting text from one encoding to another without needing to think about code points, pages or bits at all.

Say, your app *must* accept files uploaded in GB18030, but internally you are handling all data in UTF-32. A tool like `iconv` can cleanly convert the uploaded file with a one-liner like `iconv('GB18030', 'UTF-32', $string)`. That is, it will preserve the characters while changing the underlying bits:

character	GB18030 encoding	UTF-32 encoding
纔	`10111111 01101100`	`00000000 00000000 01111110 00100111`

That's all there is to it. The *content* of the string, that is, the human readable characters, didn't change, but it's now a valid UTF-32 string. If you keep treating it as UTF-32, there's no problem with garbled characters. As discussed at the very beginning though, not all encoding schemes can represent all characters. It's not possible to encode the character "纔" in any encoding scheme designed for European languages. Something Bad™ would happen if you tried to.

Unicode all the way

Precisely because of that, there's virtually no excuse in this day and age not to be using Unicode all the way. Some specialized encodings may be more efficient than the Unicode encodings for certain languages. But unless you're storing terabytes and terabytes of very specialized text (and that's *a lot* of text), there's usually no reason to worry about it. Problems stemming from incompatible encoding schemes are much worse than a wasted gigabyte or two these days. And this will become even truer as storage and bandwidth keeps growing larger and cheaper.

If your system needs to work with other encodings, convert them to Unicode upon input and convert them back to other encodings on output as necessary. Otherwise, be very aware of what encodings you're dealing with at which point and convert as necessary, if that's possible without losing any information.

Flukes

> I have this website talking to a database. My app handles everything as UTF-8 and stores it as such in the database and everything works fine, but when I look at my database admin interface my text is garbled. -- Anonymous code monkey

There are situations where encodings are handled incorrectly but things still work. An often-encountered situation is a database that's set to `latin-1` and an app that works with UTF-8 (or any other encoding). Pretty much any combination of `1`s and `0`s is valid in the single-byte `latin-1` encoding scheme. If the database receives text from an application that looks like `11100111 10111000 10100111`, it'll happily store it, thinking the app meant to store the three latin characters "ç,§". After all, why not? It then later returns this bit sequence back to the app, which will happily accept it as the UTF-8 sequence for "縜", which it originally stored. The database admin interface automatically figures out that the database is set to `latin-1` though and interprets any text as `latin-1`, so all values look garbled only in the admin interface.

That's a case of fool's luck where things happen to work when they actually aren't. Any sort of operation on the text in the database may or may not work as intended, since the database is not interpreting the text correctly. In a worst case scenario, the database inadvertently destroys all text during some random operation two years after the system went into production because it was operating on text assuming the wrong encoding.[6]

UTF-8 and ASCII

The ingenious thing about UTF-8 is that it's binary compatible with ASCII, which is the de-facto baseline for all encodings. All characters available in the ASCII encoding only take up a single byte in UTF-8 and they're the exact same bytes as are used in ASCII. In other words, ASCII

maps 1:1 unto UTF-8. Any character not in ASCII takes up two or more bytes in UTF-8. For most programming languages that expect to parse ASCII, this means you can include UTF-8 text directly in your programs:

```
$string = "漢字";
```

Saving this as UTF-8 results in this bit sequence:

```
00100100 01110011 01110100 01110010 01101001 01101110 01100111 00100000
00111101 00100000 00100010 11100110 10111100 10100010 11100101 10101101
10010111 00100010 00111011
```

Only bytes 12 through 17 (the ones starting with `1`) are UTF-8 characters (two characters with three bytes each). All the surrounding characters are perfectly good ASCII. A parser would read this as follows:

```
$string = "11100110 10111100 10100010 11100101 10101101 10010111";
```

To the parser, anything following a quotation mark is just a byte sequence which it will take as-is until it encounters another quotation mark. If you simply output this byte sequence, you're outputting UTF-8 text. No need to do anything else. The parser does not need to specifically support UTF-8, it just needs to take strings literally. Naive parsers can support Unicode this way without actually supporting Unicode. Many modern languages are *explicitly* Unicode-aware though.

Encodings and PHP

This last section deals with issues surrounding Unicode and PHP. Some portions of it are applicable to programming languages in general while others are PHP specific. Nothing new will be revealed about encodings, but concepts described above will be rehashed in the light of practical application.
PHP doesn't natively support Unicode. Except it actually supports it quite well. The previous section shows how UTF-8 characters can be embedded in any program directly without problems, since UTF-8 is backwards compatible with ASCII, which is all PHP needs. The statement *"PHP doesn't natively support Unicode"* is true though and it seems to cause a lot of confusion in the PHP community.

False promises

One specific pet-peeve of mine are the functions `utf8_encode` and `utf8_decode`. I often see nonsense along the lines of *"To use Unicode in PHP you need to `utf8_encode` your text on input and `utf8_decode` on output"*. These two functions seem to promise some sort of automagic conversion of text to UTF-8 which is "necessary" since "PHP doesn't support Unicode". If you've been following this article at all though, you should know by now that

1. there's nothing special about UTF-8 and
2. you cannot *encode* text *to* UTF-8 after the fact

To clarify that second point: All text is already encoded in *some* encoding. When you type it into the source code, it has *some* encoding. Specifically, whatever you saved it as in your text editor. If you get it from a database, it's already in *some* encoding. If you read it from a file, it's already in *some* encoding.

Text is either encoded in UTF-8 or it's not. If it's not, it's encoded in ASCII, ISO-8859-1, UTF-16 or some other encoding. If it's not encoded in UTF-8 but is supposed to contain "UTF-8 characters",[7] then you have a case of cognitive dissonance. If it does contain actual characters encoded in UTF-8, then it's actually UTF-8 encoded. Text can't contain Unicode characters without being encoded in one of the Unicode encodings.

So what in the world does `utf8_encode` *do* then?

> "Encodes an ISO-8859-1 string to UTF-8"[8]

Aha! So what the author actually wanted to say is that it *converts* the encoding of text from ISO-8859-1 to UTF-8. That's all there is to it. `utf8_encode` must have been named by some European without any foresight and is a horrible, horrible misnomer. The same goes for `utf8_decode`. These functions are useless for any purpose other than converting between ISO-8859-1 and UTF-8. If you need to convert a string from any other encoding to any other encoding, look no further than `iconv`.

`utf8_encode` is not a magic wand that needs to be swung over any and all text because "PHP doesn't support Unicode". Rather, it seems to cause more encoding problems than it solves thanks to terrible naming and unknowing developers.

Native-schmative

So what does it mean for a language to natively support or not support Unicode? It basically refers to whether the language assumes that one character equals one byte or not. For example, PHP allows direct access to the characters of a string using array notation:

```
echo $string[0];
```

If that `$string` was in a single-byte encoding, this would give us the first character. But only because "character" coincides with "byte" in a single-byte encoding. PHP simply gives us *the first byte* without thinking about "characters". Strings are *byte sequences* to PHP, nothing more, nothing less. All this "readable character" stuff is a human thing and PHP doesn't care about it.

```
01000100 01101111 01101110 00100111 01110100
D        o        n        '        t
01100011 01100001 01110010 01100101 00100001
c        a        r        e        !
```

The same goes for many standard functions such as `substr`, `strpos`, `trim` and so on. The non-support arises if there's a discrepancy between the length of a byte and a character.

```
11100110 10111100 10100010 11100101 10101101 10010111
漢                         字
```

Using `$string[0]` on the above string will, again, give us the *first byte*, which is `11100110`. In other words, a third of the three-byte character "漢". `11100110` is, by itself, an invalid UTF-8 sequence, so the string is now broken. If you felt like it, you could try to interpret that in some other encoding where `11100110` represents a valid character, which will result in some random character. Have fun, but don't use it in production.

And that's actually all there is to it. "PHP doesn't natively support Unicode" simply means that most PHP functions assume *one byte = one character*, which may lead to it chopping multi-byte characters in half or calculating the length of strings incorrectly if you're naively using non-multi-byte-aware functions on multi-byte strings. It does *not* mean that you can't use Unicode in PHP or that every Unicode string needs to be blessed by `utf8_encode` or other such nonsense.

Luckily, there's the Multibyte String extension, which replicates all important string functions in a multi-byte aware fashion. Using `mb_substr($string, 0, 1, 'UTF-8')` on the above string correctly returns `11100110 10111100 10100010`, which is the whole "漢" character. Because the `mb_` functions now have to actually think about what they're doing, they need to know what encoding they're working on. Therefore every `mb_` function accepts an `$encoding` parameter as well. Alternatively, this can be set globally for all `mb_` functions using `mb_internal_encoding`.

Using and abusing PHP's handling of encodings

The whole issue of PHP's (non-)support for Unicode is that **it just doesn't care**. Strings are byte sequences to PHP. What bytes in particular doesn't matter. PHP doesn't do anything with strings except keeping them stored in memory. PHP simply doesn't have any concept of either characters or encodings. And unless it tries to *manipulate* strings, it doesn't need to either; it just holds onto bytes that may or may not eventually be interpreted as characters by somebody else. The only requirement PHP has of encodings is that PHP source code needs to be saved in an ASCII compatible encoding. The PHP parser is looking for certain characters that tell it what to do. `$` (`00100100`) signals the start of a variable, `=` (`00111101`) an assignment, `"` (`00100010`) the start and end of a string and so on. Anything else that doesn't have any special significance to the parser is just taken as a literal byte sequence. That includes anything between quotes, as discussed above. This means the following:

1. You can't save PHP source code in an ASCII-incompatible encoding. For example, in UTF-16 a `"` is encoded as `00000000 00100010`. To PHP, which tries to read everything as ASCII, that's a `NUL` byte followed by a `"`. PHP will probably get a hiccup if every other character it finds is a `NUL` byte.

2. You can save PHP source code in any ASCII-compatible encoding. If the first 128 code points of an encoding are identical to ASCII, PHP can parse it. All characters that are in any way significant to PHP are within the 128 code points defined by ASCII. If string literals contain any code points beyond that, PHP doesn't care. You can save PHP source code in ISO-8859-1, Mac Roman, UTF-8 or any other ASCII-compatible encoding. The string literals in your script will have whatever encoding you saved your source code as.

3. Any external file you process with PHP can be in whatever encoding you like. If PHP doesn't need to parse it, there are no requirements to meet to keep the PHP parser happy.

   ```
   $foo = file_get_contents('bar.txt');
   ```

   The above will simply read the bits in `bar.txt` into the variable `$foo`. PHP doesn't try to interpret, convert, encode or otherwise fiddle with the contents. The file can even contain binary data such as an image, PHP doesn't care.

4. If internal and external encodings have to match, they have to match. A common case is localization, where the source code contains something like `echo localize('Foobar')` and an external localization file contains something along the lines of this:

   ```
   msgid  "Foobar"
   msgstr "フーバー"
   ```

   Both "Foobar" strings need to have an identical bit representation if you want to find the correct localization. If the source code was saved in ASCII but the localization file in UTF-16, the strings wouldn't match. Either some sort of encoding conversion would be necessary or the use of an encoding-aware string matching function.

The astute reader might ask at this point whether it's possible to save a, say, UTF-16 byte sequence inside a string literal of an ASCII encoded source code file, to which the answer would be: absolutely.

```
echo "UTF-16";
```

If you can bring your text editor to save the `echo "` and `";` parts in ASCII and only `UTF-16` in UTF-16, this will work just fine. The necessary binary representation for that looks like this:

```
01100101 01100011 01101000 01101111 00100000 00100010
e        c        h        o                  "
11111110 11111111 00000000 01010101 00000000 01010100
(UTF-16 marker)   U                  T
00000000 01000110 00000000 00101101 00000000 00110001
F                 -                  1
00000000 00110110 00100010 00111011
6                 "        ;
```

The first line and the last two bytes are ASCII. The rest is UTF-16 with two bytes per character. The leading `11111110 11111111` on line 2 is a marker required at the start of UTF-16 encoded text (required by the UTF-16 standard, PHP doesn't give a damn). This PHP script will happily output the string "UTF-16" encoded in UTF-16, because it simple outputs the bytes between the two double quotes, which happens to represent the text "UTF-16" encoded in UTF-16. The source code file is neither completely valid ASCII nor UTF-16 though, so working with it in a text editor won't be much fun.

Bottom line

PHP supports Unicode, or in fact *any* encoding, just fine, as long as certain requirements are met to keep the parser happy and the programmer knows what he's doing. You really only need to be careful when *manipulating* strings, which includes slicing, trimming, counting and other operations that need to happen on a *character* level rather than a *byte* level. If you're not "doing anything" with your strings besides reading and outputting them, you will hardly have any problems with PHP's support of encodings that you wouldn't have in any other language as well.

Encoding-aware languages

What does it mean for a language to support Unicode then? Javascript for example supports Unicode. In fact, any string in Javascript is UTF-16 encoded. In fact, it's the only thing Javascript deals with. You cannot have a string in Javascript that is not UTF-16 encoded. Javascript worships Unicode to the extent that there's no facility to deal with any other encoding in the core language. Since Javascript is most often run in a browser that's not a problem, since the browser can handle the mundane logistics of encoding and decoding input and output.

Other languages are simply *encoding-aware*. Internally they store strings in a particular encoding, often UTF-16. In turn they need to be told or try to detect the encoding of everything that has to do with text. They need to know what encoding the source code is saved in, what encoding a file they're supposed to read is in, what encoding you want to output text in; and they convert encodings on the fly as needed with some manifestation of Unicode as the middleman. They're doing the same thing you can/should/need to do in PHP semi-automatically behind the scenes. That's neither better nor worse than PHP, just different. The nice thing about it is that standard language functions that deal with strings Just Work™, while in PHP one needs to spare some attention to whether a string may contain multi-byte characters or not and choose string manipulation functions accordingly.

The depths of Unicode

Since Unicode deals with many different scripts and many different problems, it has a lot of depth to it. For example, the Unicode standard contains information for such problems as CJK ideograph unification. That means, information that two or more Chinese/Japanese/Korean characters actually represent the same character in slightly different writing methods. Or rules

about converting from lower case to upper case, vice-versa and round-trip, which is not always as straight forward in all scripts as it is in most Western European Latin-derived scripts. Some characters can also be represented using different code points. The letter "ö" for example can be represented using the code point U+00F6 ("LATIN SMALL LETTER O WITH DIAERESIS") or as the two code points U+006F ("LATIN SMALL LETTER O") and U+0308 ("COMBINING DIAERESIS"), that is the letter "o" combined with "¨". In UTF-8 that's either the double-byte sequence `11000011 10110110` or the three-byte sequence `01101111 11001100 10001000`, both representing the same human readable character. As such, there are rules governing *Normalization* within the Unicode standard, i.e. how either of these forms can be converted into the other. This and a lot more is outside the scope of this article, but one should be aware of it.

Final TL;DR

- Text is always a sequence of bits which needs to be translated into human readable text using lookup tables. If the wrong lookup table is used, the wrong character is used.
- You're never actually directly dealing with "characters" or "text", you're always dealing with *bits* as seen through several layers of abstractions. Incorrect results are a sign of one of the abstraction layers failing.
- If two systems are talking to each other, they always need to specify what encoding they want to talk to each other in. The simplest example of this is this website telling your browser that it's encoded in UTF-8.
- In this day and age, the standard encoding is UTF-8 since it can encode virtually any character of interest, is backwards compatible with the de-facto baseline ASCII and is relatively space efficient for the majority of use cases nonetheless.

    > Other encodings still occasionally have their uses, but you should have a concrete reason for wanting to deal with the headaches associated with character sets that can only encode a subset of Unicode.
- The days of *one byte = one character* are over and both programmers and programs need to catch up on this.

Now you should really have no excuse anymore the next time you garble some text.

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1. Yes, that means ASCII can be stored and transferred using only 7 bits and it often is. No, this is not within the scope of this article and for the sake of argument we'll assume the highest bit is "wasted" in ASCII. ↩

2. And if it isn't, it will be extended. It already has been several times. ↩

3. Please note that when I'm using the term "starting" together with "byte", I mean it from the human-readable point of view. ↩

4. Peruse the UTF-8 specification if you want to follow this with pen and paper. ↩

5. Hey, I'm a programmer, not a biologist. ↩

6. And of course there'll be no recent backup. ↩

7. A "Unicode character" is a code point in the Unicode table. "あ" is not a Unicode character, it's the Hiragana letter あ. There is a Unicode code point for it, but that doesn't make the letter itself a Unicode character. A "UTF-8 character" is an oxymoron, but may be stretched to mean what's technically called a "UTF-8 sequence", which is a byte sequence of one, two, three or four bytes representing one Unicode character. Both terms are often used in the sense of *"any letter that ain't part of my keyboard"* though, which means absolutely nothing. ↩

8. http://www.php.net/manual/en/function.utf8-encode.php ↩

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