Types & Expressions

02-201 / 02-601

Types

Variables beyond Integers

You can declare variables of several different built-in *types:*

Type	Data	Examples
`int`	Positive or negative integers	3,-200,40,42
`uint`	Non-negative integers (u = unsigned)	0, 3, 7, 11, 13
`bool`	Holds **true** or **false**	**true**
`float64`	Real, floating point number	3.14159, 12e-3, 0.23
`complex128`	Complex number (real, imaginary)	
`string`	Holds a sequence of characters	“Hello, world”

Example variables declarations:

```
var m uint = 10
var small bool = true
var big bool = m > 10
var e, pi float64 = 2.7182818285, 3.14
var name string = “Carl”
var root complex64 = 3 + 7i
```

Literals

Explicit values for variables are called *literals*.

Integer literals: a sequence of digits 0…9

```
72
6402
000734
```

String literals: a sequence of characters between quotes "

```
"Hi there"
"😄"
"1+三=4"
"3.14159"
```

Unicode strings are supported.

bool (Boolean) literals: either **true** or **false**

```
true
false
```

Floating point (real) literals: a number with a "." or "e"

```
7.
7.0
.32456
1.21212121
12E2
10E+3
11e-2
```

Tip: Use 7.0 and 0.32456 instead of 7. or .32456 (easier to read)

$aEb = a \times 10^b$ (for 12E2, 10E+3, 11e-2)

Imaginary literal: floating point literal with "i" after it

```
7.0i
7i
1e-5i
```

Expressions and Variables Must Have the Same Type

```
var a float64 = 3.0          // ok!
var b float64 = “4.0”        // ERROR! “4.0” is a string
var c int = 3.0              // ERROR! 3.0 is not an int
var d string = 7000          // ERROR!
var e int = 2                // ok
var f uint = e               // ERROR! e is an int not a uint
var ok bool = 0              // ERROR! 0 is not a bool
var ok2 bool = e > 1         // ok: boolean expression
```

```
var scale int = 2            // ok
var t float64 = 2.3*scale    // ERROR! 2.3 is a float, scale is an integer
var t2 float64 = 2*scale     // ERROR! 2*scale is an integer
```

Everything in a Go expression must have the same type.

(this is different than C, C++, Java, which are more forgiving about types)

Can Convert Between Types

Use *type(expression)* to covert *expression* to *type:*

```
var a float64 = 3.0         // ok!
var c int = int(3.0)        // ok: 3.0 converted to int
var g int = int(3.2)        // ERROR! can't convert 3.2 to int
var e int = 2               // ok
var f uint = uint(e)        // ok: e is converted to uint
var ok bool = bool(0)       // ERROR! can't covert ints to bools
```

Go really tries to avoid changing the value of a constant.

```
var time float64 = 7.2          // ok
var r int = time                // ERROR! time not an int
var round int = int(time)       // ok!!! round will equal 7
```

You know that `time` is 7.2, but Go doesn't know that, so it trusts you that you want to change `time` to an **int**.

When converting a floating point number to an int, Go will throw away the fractional part.

Conversion Challenges

```
var a, b float64 = 7.6, -13.9
var c, d int = int(a), int(b)
```

Q: What values do c and d have?

Answer:
c == 7
d == -13

```
var u int = -70
var q uint = uint(u)
```

Q: What value does q have?

Answer: it depends on your computer, but on mine:
q == 18446744073709551546

What's going on here?

More details later →

- Go (and nearly all programming languages) represent negative integers in a format called "twos-complement"
- Converting a negative number to a **uint** simply reinterprets the bits used in twos-complement to represent a positive integer
- **This is almost never what you want.**
- **Lesson: converting a negative integer to a uint is probably a bug!**

uint Challenge

```
var i uint = 10
for ; i >= 0; i = i - 1 {
    fmt.Println(i)
}
```

Q: How many times does this loop iterate?

Answer:
it never stops!

What's going on here?

- This is a common kind of bug
- **uint**s can't be negative:

```
var q uint = 0
q = q - 1
fmt.Println(q)
```

- This prints: 18446744073709551615
- q can't be negative, so "wraps around" to the largest possible **int**

Variables Have Limited Range

Type	Min	Max
`int`	-9223372036854775808	9223372036854775807
`uint`	0	18446744073709551615
`float64`	-1.797693134862315708145274237317043567981e+308	1.797693134862315708145274237317043567981e+308

```
var i int = 9223372036854775807
fmt.Println(i+1)
```

Q: What does the above print?

Answer:

-9223372036854775808

i+1 is too big for an **int**, so it wraps around to the smallest possible **int**.

This is called *overflow* and its usually a bug!

Lesson: if you have very big or very small numbers, you have to do something special.

Binary Numbers

Base 10 (decimal) notation:

4 2 5 6

$$
\begin{array}{r}
6 \times 10^{0} \\
5 \times 10^{1} \\
2 \times 10^{2} \\
+ \; 4 \times 10^{3} \\
\hline
4\,2\,5\,6
\end{array}
$$

Computers store the numbers in binary because it has transistors that can encode 0 and 1 efficient

Each 0 and 1 is a *bit.*

Built-in number types each have a maximum number of bits.

Base 2 (binary) notation:

1 0 0 0 0 1 0 1 0 0 0 0 0

$$
\begin{array}{r}
0 \times 2^{0} \\
0 \times 2^{1} \\
0 \times 2^{2} \\
0 \times 2^{3} \\
0 \times 2^{4} \\
1 \times 2^{5} \\
0 \times 2^{6} \\
1 \times 2^{7} \\
0 \times 2^{8} \\
0 \times 2^{9} \\
0 \times 2^{10} \\
0 \times 2^{11} \\
+ \; 1 \times 2^{12} \\
\hline
\end{array}
$$

4 2 5 6 = 1 0 0 0 0 1 0 1 0 0 0 0 0

Variables with Different Ranges

Type	Number of bits
`int`	32 or 64 depending on your computer
`uint`	32 or 64 depending on your computer (but always same size as int)
`int8 / uint8`	8
`int16 / uint16`	16
`int32 / uint32`	32
`int64 / uint64`	64
`float32`	32
`float64`	64
`complex64`	32 for each of the real and imaginary parts
`complex128`	64 for each of the real and imaginary parts
`byte`	another word for `int8`
`rune`	another word for `int32`

Tip: use `int`, `float64`, and `complex128` unless you have memory limitations.

Type Inference in var and := Statements

You can often omit specifying the type if Go can guess what type it should be:

```
var a = 3                // a will be an int
var b = uint(a*a)        // b will be a uint
var d = "hi there"       // d will be a string
var ok = true            // ok will be a bool
var ok2 = e > 1          // ok2 will be a bool
var z = 3.0              // a will be a float64
q := 1e-23               // q will be a float64
var theta = 3 + 2.0i     // theta will be a complex128
var t2 = 2*theta         // t2 will be complex128
result := f(a,b,d)       // will be the return type of f
```

Integer literals (3, -10, etc.) cause **int**s to be inferred

The larger float and complex size types (`float64`, `complex128`) are always used when inferring from literals of those types.

The Lesson of Types

Types in an expression must agree.

Be sure you don't corrupt your data by converting to the wrong type.

Everything else is basically details that you have to know to program, but that shouldn't be forefront in your mind.

Expressions & Operators

Integer Operations

`a + b` addition

`a - b` subtraction

`a * b` multiplication

`-a` negation

`+a` doesn't do anything, but available for symmetry with -

`a / b` ***integer*** division: 2/3 = 0; 10/3 = 3; -10/3 = -3
results are truncated toward 0

If q = x / y and r = x % y then
x = q*y + r and |r| < |y|

`a % b` *modulus* (aka remainder):
13 % 2 = 1; 10 % 2 = 0; 10 % 3 = 1
-10 % 3 = -1 (since -10 = 3*(-3) - 1)

Increment and Decrement Statements

Adding and subtracting 1 is so common there is a special notation for it:

`a++` is the same as `a = a + 1`

`a--` is the same as `a = a - 1`

This is particularly useful in **for** loops:

```
for i := 1; i <= n; i++ {
  // body of for loop
}
```

Float and Complex Operators

`a + b` `a - b` `a * b` `-a` `+a`

`a / b`

floating point division:

2.0/3.0 = 0.6666666666666666
10.0/3.0 = 3.3333333333333335
-10.0/3.0 = -3.3333333333333335

results are of limited precision
b can't be 0

Boolean Operators

`a && b` **true** if and only if a and b are both **true**

`a || b` **true** if and only if one of a or b is **true**

Comparison Operators

`a < b` `a > b`

`a <= b` `a >= b`

`a == b` equals

`a != b` not equals

Operator Precedence

```
x * y + z
```

= (x*y) + z

Precedence	Operator
5	* / %
4	+ -
3	== != < <= > >=
2	&&
1	||

applied first → 5

applied last → 1

Use () to group operators and change the order they are applied: x*(y+z)

Tip: don't remember the order of operations: always use () to make the order explicit.

Example Expressions

```
a + b / 3 + 2
```

```
(a+b) / 3 + 2
```

```
-a*(3+c - d)
```

Strings & The Motivation for Types

String Operator

```
s1 + s2
```

concatenation

Places one string after another:

```
“hi” + “there” == “hithere”
“what’s “ + “up” + “ doc?” == “what’s up doc?”
```

Question: What’s the value of a?

```
c := 42
a := “hi” + string(c)
```

Answer: this is an error, since “hi” has type **string** and 3 has type **int**.

String Representations

The name “string” is meant to suggest a sequence of characters strung together.

H	e	l	l	o	,		W	o	r	l	d	!

Each item in a string is called a *character*.

Characters are stored as binary numbers (as is *all* data in the computer).

The type of a variable tells your program how to interpret those numbers as data that makes sense in the world.

int means “interpret these binary digits as an integer”
float64 means “interpret these binary digits as a real number”
string means “interpret these binary digits as a sequence of characters”

Question: What’s the value of a?

```
a := “hi” + string(42)
```

ASCII Chart
(You don’t need to know these numbers)

Binary	Dec	Glyph
110 0000	96	`
110 0001	97	a
110 0010	98	b
110 0011	99	c
110 0100	100	d
110 0101	101	e
110 0110	102	f
110 0111	103	g
110 1000	104	h
110 1001	105	i
110 1010	106	j
110 1011	107	k
110 1100	108	l
110 1101	109	m
110 1110	110	n
110 1111	111	o
111 0000	112	p
111 0001	113	q
111 0010	114	r
111 0011	115	s
111 0100	116	t
111 0101	117	u
111 0110	118	v
111 0111	119	w
111 1000	120	x
111 1001	121	y
111 1010	122	z
111 1011	123	{
111 1100	124	|
111 1101	125	}
111 1110	126	~

Binary	Dec	Glyph
100 0000	64	@
100 0001	65	A
100 0010	66	B
100 0011	67	C
100 0100	68	D
100 0101	69	E
100 0110	70	F
100 0111	71	G
100 1000	72	H
100 1001	73	I
100 1010	74	J
100 1011	75	K
100 1100	76	L
100 1101	77	M
100 1110	78	N
100 1111	79	O
101 0000	80	P
101 0001	81	Q
101 0010	82	R
101 0011	83	S
101 0100	84	T
101 0101	85	U
101 0110	86	V
101 0111	87	W
101 1000	88	X
101 1001	89	Y
101 1010	90	Z
101 1011	91	[
101 1100	92	\
101 1101	93	]
101 1110	94	^
101 1111	95	_

Binary	Dec	Glyph
010 0000	32	(space)
010 0001	33	!
010 0010	34	"
010 0011	35	#
010 0100	36	$
010 0101	37	%
010 0110	38	&
010 0111	39	'
010 1000	40	(
010 1001	41	)
010 1010	42	*
010 1011	43	+
010 1100	44	,
010 1101	45	-
010 1110	46	.
010 1111	47	/
011 0000	48	0
011 0001	49	1
011 0010	50	2
011 0011	51	3
011 0100	52	4
011 0101	53	5
011 0110	54	6
011 0111	55	7
011 1000	56	8
011 1001	57	9
011 1010	58	:
011 1011	59	;
011 1100	60	<
011 1101	61	=
011 1110	62	>
011 1111	63	?

Logical interpretation:	H	e	l	l	o	,		W	o	r	l	d	!
Representation in the computer:	72	101	108	108	111	44	32	87	111	114	108	100	33

Packages

Packages

- Packages are collections of functions you can use in your program.

- Go provides many built-in packages →

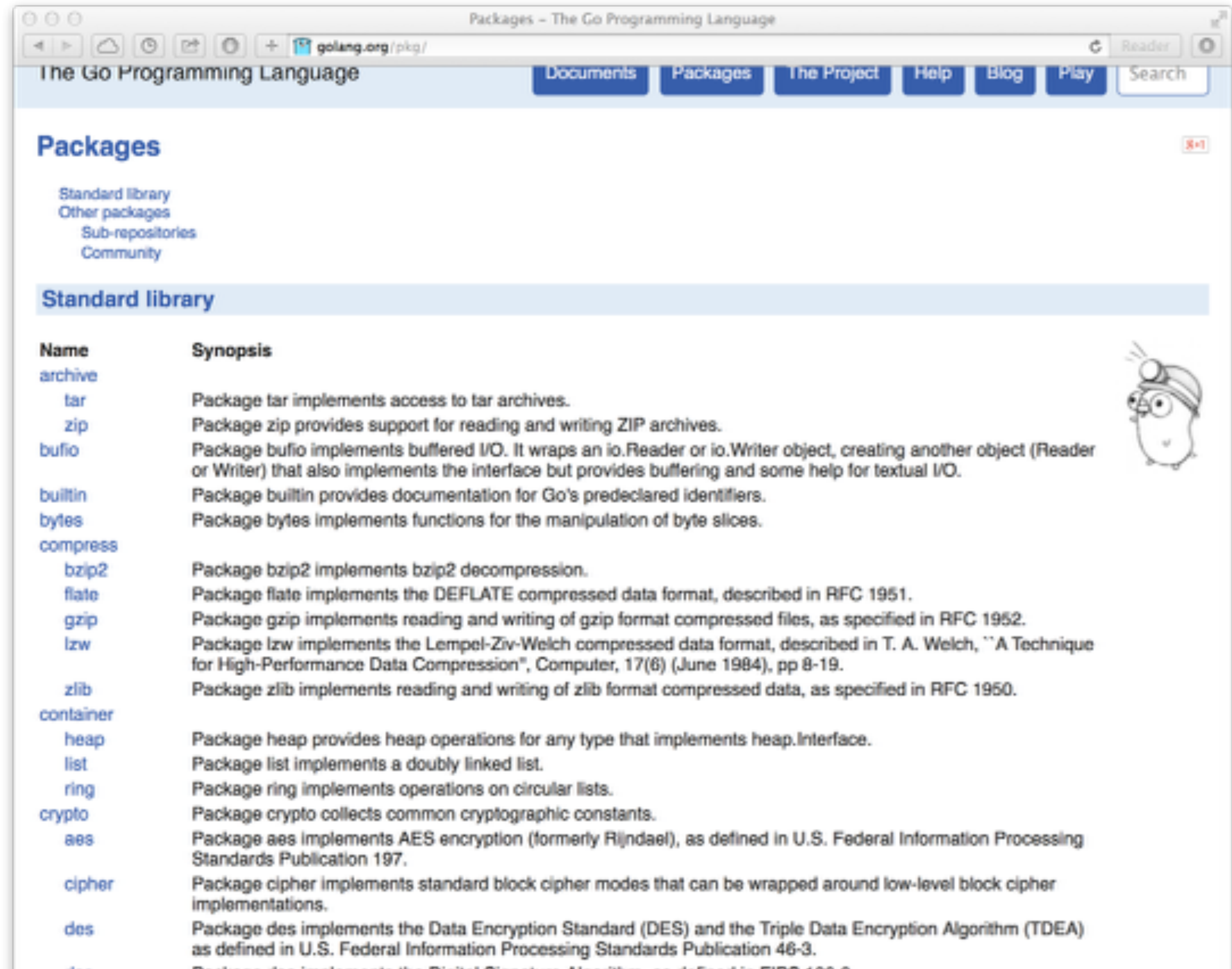
- Enable the the use of a package with:

```
import “packageName”
```

  at the top of your program.

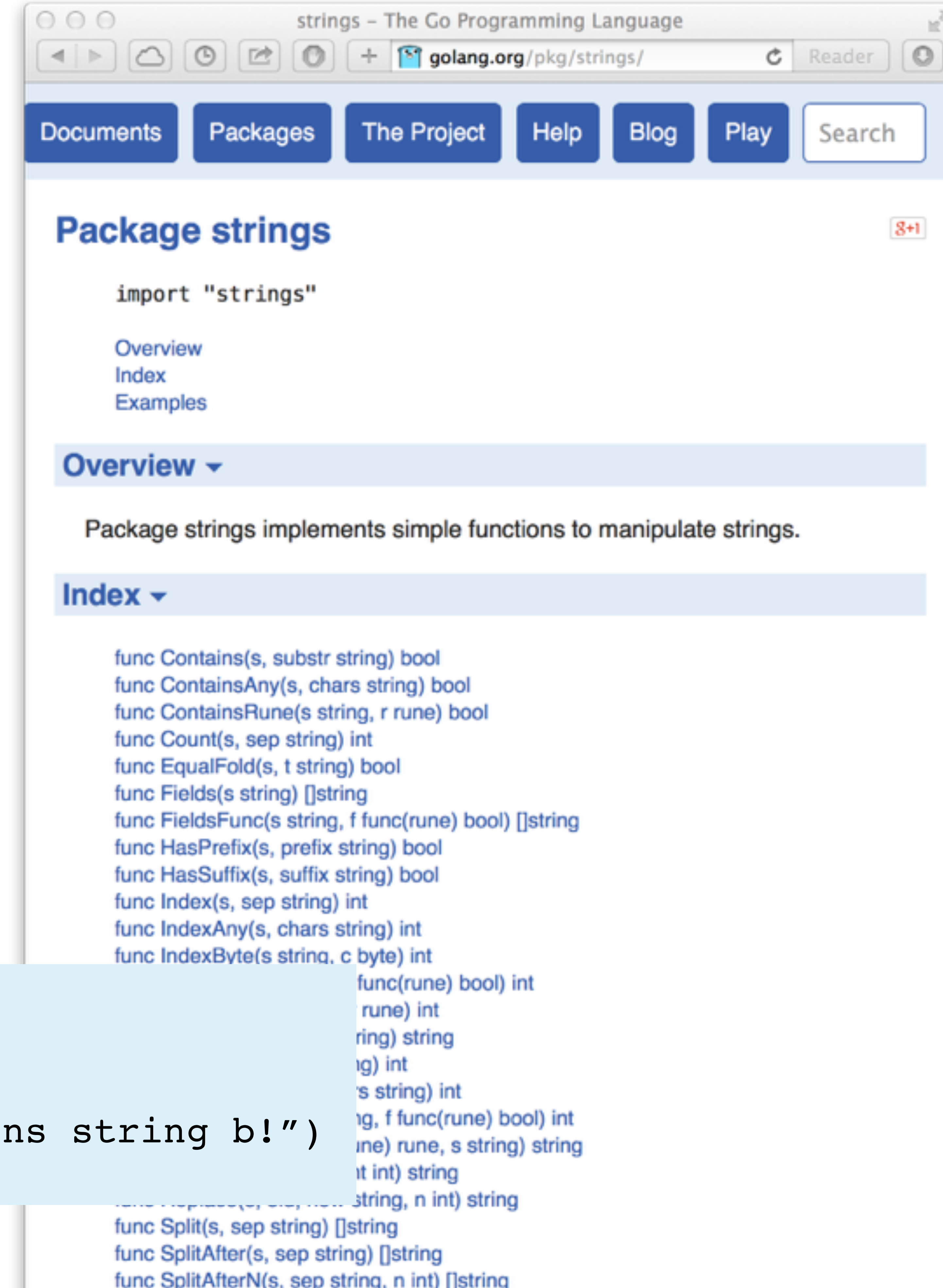
- Get a list of built-in packages at: http://golang.org/pkg/

- `fmt` package provides the `fmt.Print` and `fmt.Println` functions we’ve used a lot.



String Package

- Lets you manipulate strings.
- A very large part of programming in practice is looking up how to use functions in existing packages.
- This example tests whether one string has another as a substring:




```
var a = "hi, there"
var b = "the"
if strings.Contains(a, b) {
    fmt.Println("String a contains string b!")
}
```

strconv Package

Back to our problem: how do we get this:

```
a := "hi" + string(42)
```

to do what we want?

Inside of the strconv package, there are these functions:

```
func FormatBool(b bool) string
func FormatFloat(f float64, fmt byte, prec, bitSize int) string
func FormatInt(i int64, base int) string
func FormatUint(i uint64, base int) string
func Itoa(i int) string
```

Takes in an **int64** and returns a **string**

FormatInt also allows you to set the base (10, etc.) of the representation.

Using the Itoa() function gives us our desired result:

```
a := "hi" + strconv.Itoa(42)
```

math Package

Might find:

```
math.Abs()
math.Pow10()
```

functions useful for the `KthDigit` question on homework 1.

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func Abs(x float64) float64
func Acos(x float64) float64
func Acosh(x float64) float64
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func Atan(x float64) float64
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Types & Expressions Summary

- Every variable has a type that tells Go how to interpret the bits that represent that variable.
- In Go, everything in an expression must have the same type.
- You can convert between types by using the type name like a function: **int**(myFloatVar).
- Consistent with other types: **string**(103) reinterprets the number 103 as a string. It does not turn 103 into a string “103” of the decimal representation of 103.
- Packages provide lots of useful pre-defined functions, one of which is to convert numbers into strings (and vice versa).

Go Summary

90% of programming is the combination of these things:

functions: basic building block: define new “things” the computer can do

variables: units of data that your program can manipulate

types: tell Go what kind of data is in each variable

if…else: select statements to execute based on some condition

for: repeat statements while some condition is true