

Poker Hand

by ToF

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$\lambda \ \lambda \ \lambda$

1 We have a problem...

What is this : "8♥"?

A [String](#).

Yes. What does it represent?

An eight of hearts, or 8♥.

What does "7♣ 6♦ 9♠" represent?

Some others cards: 7♣, 6♦, and 9♠.

Right. And what does "A♥ K♥ Q♥ J♥ T♥" represent?

It represents victory: it's a royal flush.

What is the best we can do with the following:
4♦ 2♦ K♠ K♦ 9♦ 3♣ 6♦?

A flush.

And with 9♣ A♥ K♠ K♦ 9♦ 3♣ 6♦?

Two pairs.

Correct. And with A♣ Q♣ K♠ K♦ 9♦ 3♣?

Nothing, because there are less than seven cards.

And with 9♥ 5♠?

Nothing, for the same reason.

That's right.
What about K♣ 9♠ K♠ K♦ 9♦ 3♣ 6♦?

It's a full house. Say, why are you showing me all these cards?

Because we have a problem, and I wanted to be sure you know the basics about *Poker*.

Show me what the problem is.

We have to write a program with, given this input:

K♣ 9♠ K♠ K♦ 9♦ 3♣ 6♦
 9♣ A♥ K♠ K♦ 9♦ 3♣ 6♦
 A♣ Q♣ K♠ K♦ 9♦ 3♣
 9♥ 5♠
 4♦ 2♦ K♠ K♦ 9♦ 3♣ 6♦
 7♠ T♠ K♠ K♦ 9♦

These are the cards of some players in a game of *Texas Hold'em*. Right?

– right – ..would output this:

K♣ 9♠ K♠ K♦ 9♦ 3♣ 6♦ Full House (winner)
 9♣ A♥ K♠ K♦ 9♦ 3♣ 6♦ Two Pair
 A♣ Q♣ K♠ K♦ 9♦ 3♣
 9♥ 5♠
 4♦ 2♦ K♠ K♦ 9♦ 3♣ 6♦ Flush
 7♠ T♠ K♠ K♦ 9♦

I see.

What do you see?

Some lines are just left as they are.
 Some lines are marked with the ranking of the best possible hand given the cards on the line.
 The line with the best ranking is marked as the winner.

Do you think we can solve the problem?

Yes, provided we have the good tools.

What is the value of: `filter even [4,8,0,7]`?

`[4,8,0]`

What is the value of: `subsequences "abc"`?

`["", "a", "b", "ab", "c", "ac", "bc", "abc"]`

And of the expression: `maximum [4,8,0,7]`?

8

What about: `zip [3,5,2] "abc"`?

`[(3,'a'),(5,'b'),(2,'c')]`

and the expression: `zipWith (*) [3,5,2] [4,9,7]`?

`[12, 45, 14]`

What is the value of:
`words "time flies like an arrow"`?

`["time", "flies", "like", "an", "arrow"]`

What is the value of: `compare "time" "arrow"`?

GT, because `"time" > "arrow"`

What is the value of:
`comparing length "time" "arrow"`?

LT, because `(length "time") < (length "arrow")`

Do you want to solve the problem?

Let's make some tea first.

2 Dealing with Cards

What is something simple we could begin to solve?

Comparing cards.

How do we proceed?

Write a failing test.

Ok. Let compare a 6♣ and a 6♠. These two cards should be considered equals in value.

```
module Tests
where
import Test.HUnit

main = runTestTT $ TestList
    [compare "6♣" "6♠" ~?= EQ]
```

■ The result is failure:

```
expected: EQ
but got: LT
```

But it's not a big matter, since we're comparing [Strings](#) when we should compare [Cards](#).

What is the result?

What is a [Card](#)?

It's a new data type.

How do I create values of this type?

Pretend you have a function from [String](#) to [Card](#).

Ok. I'll just call that function *card* :

```
main = runTestTT $ TestList
    [compare (card "6♣") (card "6♠") ~?= EQ]
```

■ Error, as expected. Let me just write the function.

```
module PokerHand
where

card :: String → Card
```

What now?

■ This results in two errors:

The type signature for 'card' lacks an accompanying binding

Not in scope: type constructor or class 'Card'

Can you write provide the missing parts ?

■ Now we have another error:

No instance for (Ord Card) arising from a use of 'compare'
Possible fix: add an instance declaration for (Ord Card)

Should we make the suggested fix?

■ Now we have this:

No instance for (Eq Card) arising from a use of 'compare'
Possible fix: add an instance declaration for (Eq Card)

Of course, this is just a *fake* implementation of the function *card*.

Here you go:

```
main = runTestTT $ TestList
  [compare (card "6♣") (card "6♠") ~?= EQ
  ,compare (card "6♣") (card "5♠") ~?= GT]
```

How do we make it pass?

■ Just make the test pass. I don't like having to think on a red bar.

■ OK, this is the *Card* type:

```
data Card = C
```

It has just a single value, *C*. And we implement the function

```
card :: String → Card
card _ = C
```

which is just producing the single value.

■ Sure:

```
data Card = C deriving (Ord)

card :: String → Card
card _ = C
```

■ Again, let's do what the compiler suggests

```
data Card = C deriving (Ord,Eq)

card :: String → Card
card _ = C
```

■ And the test passes.

Then write another test.

■ We have to compare the rank values of the cards, so we should store this value in the *Card* type:

```
data Card = C Value deriving (Ord,Eq)
type Value = Int

card :: String → Card
card _ = C 0
```

■ Of course, the test now fails, as we must calculate the real value instead of returning zero. Let's think..

■ Let's play "*fake it 'til you make it*" then:

```
card :: String → Card
card ['6',_] = C 6
card ['5',_] = C 5
```

■ Now it's obvious.

■ Indeed, just convert from `Char` to `Int`, using the `ord` function. Do it.

■ Ok!

```
module PokerHand
where
import Char

data Card = C Value deriving (Ord,Eq)
type Value = Int

card :: String → Card
card [c,_] = C $ (ord c) - (ord '0')
```

■ Done.

Done? I think I have a new test to write. But first I'll do some refactoring, too.

```
main = runTestTT $ TestList
  [compare (card "6♣") (card "6♠") ~?= EQ
  ,compare (card "6♣") (card "5♠") ~?= GT]
```

You know about `comparing` right?

Yes, and so does *GHCI*:

```
comparing :: (Ord a) => (b → a) → b → b → Ordering
--Defined in Data.Ord
```

`comparing` takes a function from a type `b` to an ordered type `a`, two values of type `b` and gives the comparison using the given function.

Yes, so I can compare `Strings` using the `card` function:

```
import Data.Ord (comparing)

main = runTestTT $ TestList
  [comparing card "6♣" "6♠" ~?= EQ
  ,comparing card "6♣" "5♠" ~?= GT]
```

■ Nice!

Now for my new test:

```
main = runTestTT $ TestList
  [comparing card "6♣" "6♠" ~?= EQ
  ,comparing card "6♣" "5♠" ~?= GT
  ,comparing card "T♣" "J♠" ~?= LT]
```

■ We're expecting `LT` but get `GT`. Can you make it pass?

■ Sure:

```
card :: String → Card
card ['J',_] = C 11
card ['T',_] = C 10
card [c,_] = C $ (ord c) - (ord '0')
```

■ We just have to add special cases.

Good. Here's a new one:

```
main = runTestTT $ TestList
  [comparing card "6♣" "6♠" ~?= EQ
  ,comparing card "6♣" "5♠" ~?= GT
  ,comparing card "T♣" "J♠" ~?= LT
  ,comparing card "K♠" "A♣" ~?= LT]
```

■ Ok.

```
card :: String → Card
card ['A',_] = C 14
card ['K',_] = C 13
card ['J',_] = C 11
card ['T',_] = C 10
card [c,_] = C $ (ord c) - (ord '0')
```

■ That's easy: give each card its value.

We forgot the Queen value:

```
main = runTestTT $ TestList
  [comparing card "6♣" "6♠" ~?= EQ
  ,comparing card "6♣" "5♠" ~?= GT
  ,comparing card "T♣" "J♠" ~?= LT
  ,comparing card "K♠" "A♠" ~?= LT
  ,comparing card "Q♣" "K♣" ~?= LT]
```

■ Sure:

```
card :: String → Card
card ['A',_] = C 14
card ['K',_] = C 13
card ['Q',_] = C 12
card ['J',_] = C 11
card ['T',_] = C 10
card [c,_] = C $ (ord c) - (ord '0')
```

Can you add it?

■ And we are done with card values.

We are, but these tests are a bit heavy. Can you think of a way to avoid repeating all these comparisons?

Yes: we could test the sorting of a deck.

```
module Tests
where
import Test.HUnit
import PokerHand
import Data.List (sort)

ud = map card ["A♠","2♠","T♠","K♠","9♠","Q♠","J♠"]
sd = map card ["2♠","9♠","T♠","J♠","Q♠","K♠","A♠"]

main = runTestTT $ TestList
  [sort ud ~?= sd]
```

■ Yes, but we have a new problem.

Is that what you mean?

■ Indeed:

No instance for (Show Card) arising from a use of '~?='

Possible fix: add an instance declaration for (Show Card)

Should we follow the suggestion?

■ No. I don't think the `Card` type should derive the `Show` class just for testing reasons.

Then should we get back to the previous version of our tests?

I have a better idea: instead of comparing lists of `Cards` we can compare lists of `Strings`.

■ Comparing the `Strings` ? Ok:

```
ud = ["A♠","2♠","T♠","K♠","9♠","Q♠","J♠"]
sd = ["2♠","9♠","T♠","J♠","Q♠","K♠","A♠"]

main = runTestTT $ TestList
  [sort ud ~?= sd]
```

■ Of course: we don't use `Cards` any more! We should compare the `Strings` using the `card` function. The function

```
sortBy :: (a → a → Ordering) → [a] → [a]
```

allows us to do that.

■ But now the test fails:

```
expected: ["2♠","9♠","T♠","J♠","Q♠","K♠","A♠"]
but got: ["2♠","9♠","A♠","J♠","K♠","Q♠","T♠"]
```

Do you see why?

You mean like this:

```
import Data.Ord (comparing)
import Data.List (sortBy)

ud = ["A♣", "2♣", "T♣", "K♣", "9♣", "Q♣", "J♣"]
sd = ["2♣", "9♣", "T♣", "J♣", "Q♣", "K♣", "A♣"]

main = runTestTT $ TestList
      [sortBy (comparing card) ud ~= sd]
```

■ Yes!

I wonder what would the test show if it failed. Let's falsify it:

```
import Data.Ord (comparing)
import Data.List (sortBy)

ud = ["3♣", "2♣", "T♣", "K♣", "9♣", "Q♣", "J♣"]
sd = ["2♣", "9♣", "T♣", "J♣", "Q♣", "K♣", "A♣"]

main = runTestTT $ TestList
      [sortBy (comparing card) ud ~= sd]
```

■ Here is what the message says:

```
expected: ["2♣", "9♣", "T♣", "J♣", "Q♣", "K♣", "A♣"]
but got:  ["2♣", "3♣", "9♣", "T♣", "J♣", "Q♣", "K♣"]
```

The test properly outputs the results as a list of [Strings](#). You can un-falsify the test now.

I just changed the first value of the unsorted desk.

Yes.

Oh, and using [words](#) for the definition of our decks would make the code prettier.

You are right. So this is the test code:

```
module Tests
where
import Test.HUnit
import PokerHand
import Data.Ord (comparing)
import Data.List (sortBy)

ud = words "A♣ 2♣ T♣ K♣ 9♣ Q♣ J♣"
sd = words "2♣ 9♣ T♣ J♣ Q♣ K♣ A♣"

main = runTestTT $ TestList
      [sortBy (comparing card) ud ~= sd]
```

■ And this is the tested code:

```
module PokerHand
where
import Char

data Card = C Value deriving (Ord, Eq)
type Value = Int

card :: String → Card
card ['A', _] = C 14
card ['K', _] = C 13
card ['Q', _] = C 12
card ['J', _] = C 11
card ['T', _] = C 10
card [c, _] = C $ (ord c) - (ord '0')
```

Are we done with comparing *Cards*?

Not yet, but it's time for a break.

3 Looking for a Flush

What is the next task with regard to card comparison ?

We need to compare suits so that we can find a *flush*.

Ok I'll write a test:

```
ud = words "A♠ 2♠ T♠ K♠ 9♠ Q♠ J♠"
sd = words "2♠ 9♠ T♠ J♠ Q♠ K♠ A♠"

main = runTestTT $ TestList
  [sortBy (comparing card) ud ~?= sd
  ,flush (cards "A♠ T♠ 3♠ 4♠ 2♠") ~?= True]
  where cards = map card . words
```

■ Let's write a function *flush*

```
flush :: [Card] → Bool
flush _ = True
```

■ Done.

I see. Still the *fake it 'til you make it* approach.

This is the simplest thing that makes the test pass.

Ok. Here is another test:

```
main = runTestTT $ TestList
  [sortBy (comparing card) ud ~?= sd
  ,flush (cards "A♠ T♠ 3♠ 4♠ 2♠") ~?= True
  ,flush (cards "A♠ T♠ 3♠ 4♠ 2♠") ~?= False ]
  where cards = map card . words
```

■ I don't think so.

Can you make it pass ?

What is missing ?

The `Card` type doesn't include suits.

How can we change that ?

Add a failing test on getting **Suits** from **Cards**.

Ok, then I'll replace my last test with this one:

```
main = runTestTT $ TestList
  [sortBy (comparing card) ud ~?= sd
  ,flush (cards "A♣ T♣ 3♣ 4♣ 2♣") ~?= True
  ,map suit (cards "A♣ A♦ A♣ A♠") ~?= ['♣','♦','♣','♠']]
  where cards = map card . words
```

■ First we need a *suit* function:

```
type Suit = Char

suit :: Card → Suit
suit _ = '♣'
```

Can you make this one pass ?

■ Now the test is failing.

What else is needed ?

■ We must store the suit into to the **Card** type:

```
data Card = C Value Suit deriving (Ord,Eq)
```

And then we have to capture the suit in the *card* function:

```
card :: String → Card
card ['A',s] = C 14 s
card ['K',s] = C 13 s
card ['Q',s] = C 12 s
card ['J',s] = C 11 s
card ['T',s] = C 10 s
card [c,s] = C ((ord c) - (ord '0')) s
```

■ The code in the *card* function is a bit tedious, don't you think ?

■ I'll refactor it when the bar is green. I still have to remove the *fake* on *suit*:

```
suit :: Card → Suit
suit (C _ s) = s
```

■ And now we can get **Suits** from **Cards**.

Good. Refactor the code, now.

■ Alright. First I can discard the *suit* function by declaring labels:

```
data Card = C { value :: Value, suit :: Suit }
              deriving (Ord,Eq)
```

Then I can separate concerns in the *card* function:

```
card :: String → Card
card [v,s] = C (toValue v) s
  where
    toValue 'A' = 14
    toValue 'K' = 13
    toValue 'Q' = 12
    toValue 'J' = 11
    toValue 'T' = 10
    toValue c = ((ord c) - (ord '0'))
```

■ Done.

Can I add my test on *flush* now ?

Yes.

Here it is:

```
main = runTestTT $ TestList
  [sortBy (comparing card) ud ~?= sd
  ,flush (cards "A♠ T♠ 3♣ 4♣ 2♠") ~?= True
  ,map suit (cards "A♠ A♠ A♠ A♠") ~?= ['♠','♠','♠','♠']
  ,flush (cards "A♠ T♠ 3♣ 4♣ 2♠") ~?= False]
  where cards = map card . words
```

■ Sure:

```
flush :: [Card] → Bool
flush (c:_) = suit c == '♠'
```

Do you see how to make it pass ?

■ As you see, it's a *fake*.

In that case, I'll add a new test :

```
main = runTestTT $ TestList
  [sortBy (comparing card) ud ~?= sd
  ,flush (cards "A♠ T♠ 3♣ 4♣ 2♠") ~?= True
  ,map suit (cards "A♠ A♠ A♥ A♠") ~?= ['♠','♠','♠','♠']
  ,flush (cards "A♠ T♠ 3♣ 4♣ 2♠") ~?= False
  ,flush (cards "A♠ T♠ 3♣ 4♣ 2♠") ~?= True]
  where cards = map card . words
```

■ Ok. I think I can take a more general approach:

```
flush :: [Card] → Bool
flush (c:cs) = all (\x → suit x == suit c) cs
```

■ Of course, we're assuming that the *flush* function will always consume non-empty lists.

Ok. This are the tests so far:

```
module Tests
where
import Test.HUnit
import PokerHand
import Data.Ord (comparing)
import Data.List (sort,sortBy)

ud = words "A♠ 2♠ T♠ K♠ 9♣ Q♣ J♠"
sd = words "2♠ 9♠ T♠ J♠ Q♣ K♠ A♠"

main = runTestTT $ TestList
  [sortBy (comparing card) ud ~?= sd
  ,map suit (cards "A♠ A♠ A♥ A♠") ~?= ['♠','♠','♠','♠']
  ,flush (cards "A♠ T♠ 3♣ 4♣ 2♠") ~?= True
  ,flush (cards "A♠ T♠ 3♣ 4♣ 2♠") ~?= False
  ,flush (cards "A♠ T♠ 3♣ 4♣ 2♠") ~?= True]
  where cards = map card . words
```

And this is the tested code:

```
module PokerHand
where
import Char

data Card = C { value :: Value, suit :: Suit }
               deriving (Ord,Eq)
type Value = Int
type Suit = Char

card :: String → Card
card [v,s] = C (toValue v) s
  where
    toValue 'A' = 14
    toValue 'K' = 13
    toValue 'Q' = 12
    toValue 'J' = 11
    toValue 'T' = 10
    toValue c = ((ord c) - (ord '0'))

flush :: [Card] → Bool
flush (c:cs) = all (\x → suit x == suit c) cs
```

Are we done with comparing cards ?

I think so. Let's have lunch.

4 “Pair” Programming

Now that we have suitable tools to compare cards, what should we do ?

Compare hands.

How do we form a `Hand` ?

We’ll write a function:

```
type Hand = [Card]
hand :: String → Hand
```

Good. But we should write a test before writing code.

Go on.

What is the simplest hand comparison we could write a test for ?

Let’s try comparing simple “High Cards” hands.

Ok. Here is a new test:

This last test is a bit long.

```
main = runTestTT $ TestList
  [sortBy (comparing card) ud ~?= sd
  ,map suit (cards "A♠ A♦ A♥ A♣") ~?= ['♠','♦','♥','♣']
  ,flush (cards "A♠ T♠ 3♠ 4♠ 2♠") ~?= True
  ,flush (cards "A♠ T♠ 3♠ 4♠ 2♣") ~?= False
  ,flush (cards "A♠ T♠ 3♠ 4♠ 2♠") ~?= True
  ,comparing hand "6♠ 4♦ A♠ 3♠ K♠" "8♠ J♥ 7♦ 5♥ 6♣" ~?= GT]
  where cards = map card . words
```

Ok, let’s rephrase it this way:

```
main = runTestTT $ TestList
  [sortBy (comparing card) ud ~?= sd
  ,map suit (cards "A♠ A♣ A♥ A♦") ~?= ['♠','♣','♥','♦']
  ,flush (cards "A♠ T♠ 3♠ 4♠ 2♠") ~?= True
  ,flush (cards "A♠ T♠ 3♠ 4♠ 2♠") ~?= False
  ,flush (cards "A♠ T♠ 3♠ 4♠ 2♠") ~?= True
  , "6♠ 4♠ A♠ 3♠ K♠" 'beat' "8♥ J♥ 7♦ 5♥ 6♠"
  ]
where cards = map card . words
      beat h g = comparing hand h g ~?= GT
```

■ OK. We need to create the *hand* function. But first I will borrow your *cards* utility function.

Sure, take it to your side.

```
main = runTestTT $ TestList
  [sortBy (comparing card) ud ~?= sd
  ,map suit (cards "A♠ A♣ A♥ A♦") ~?= ['♠','♣','♥','♦']
  ,flush (cards "A♠ T♠ 3♠ 4♠ 2♠") ~?= True
  ,flush (cards "A♠ T♠ 3♠ 4♠ 2♠") ~?= False
  ,flush (cards "A♠ T♠ 3♠ 4♠ 2♠") ~?= True
  , "6♠ 4♠ A♠ 3♠ K♠" 'beat' "8♥ J♥ 7♦ 5♥ 6♠"
  ]
where beat h g = comparing hand h g ~?= GT
```

■ Thanks

```
cards :: String → [Cards]
cards = map card . words
```

In fact forming a hand is just making *Cards* from *Strings* and sorting them:

```
hand :: String → Hand
hand = sort . cards
```

■ Except we get *LT* instead of *GT*.

Of course: we’re sorting in the wrong order. How can we change the sorting order ?

We can use *sortBy* and give it the proper comparison function.

Given what *GHCI* tells us about *sort*, *sortBy* and *compare*:

```
:type sort
sort :: (Ord a) => [a] -> [a]
:type sortBy
sortBy :: (a -> a -> Ordering) -> [a] -> [a]
:type compare
compare :: (Ord a) => a -> a -> Ordering
```

We know that *sortBy compare* is equivalent to *sort*. How can we reverse the result given by *compare* ?

By flipping its arguments. *flip f a b* is equivalent to *f b a*. Thus:

```
hand :: String → Hand
hand = sortBy (flip compare) . cards
```

■ will do the trick.

Ok. What is the next hand that can beat a *High Card* ?

A *Pair*.

Then I’ll write this test:

```
, "6♠ 4♠ A♠ 3♠ K♠" 'beat' "8♥ J♥ 7♦ 5♥ 6♠"
, "5♥ 4♦ 3♥ 2♦ 2♥" 'beat' "A♥ K♥ Q♦ J♦ 9♥"
where beat h g = comparing hand h g ~?= GT
```

■ The test fails. We have to detect that the hand is a pair, and use that information to trump the usual card comparison.

Meaning: the lowest *Pair* should beat the highest *High Card*.

How do we do that?

■ We declare that in the *Hand* type, a *Pair* is always greater than a *High Card*.

How do we order values within a type?

■ We declare it as an algebraic type, saying we either have a *HighCard* followed by a list of *Cards*, or a *Pair*:

```
data Hand = HighCard [Card]
          | Pair
          deriving (Ord,Eq)
```

■ Of course, now the *hand* function is now of the wrong type.

The compiler says:

Couldn't match expected type 'Hand'
against inferred type '[Card]'

In the expression:

```
sortBy (flip compare) . cards
```

In the definition of 'hand':

```
hand = sortBy (flip compare) . cards
```

Can you arrange this ?

Yes. Let's begin by forcing the function to a *HighCard* value:

```
hand :: String → Hand
hand = HighCard . sortBy (flip compare) . cards
```

■ and we're back with a failing test instead of a compiler error.

Can you *fake* the correct construction that would make the test pass ?

Yes. Let's just insert a special case:

```
hand :: String → Hand
hand "5♥ 4♦ 3♥ 2♦ 2♥" = Pair
hand s = HighCard $ sortBy (flip compare) $ cards s
```

■ And the test is passing.