CMPT 373
Software Development Methods

Designing APIs for Simplicity and Preventing Errors

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  - A specification of how things interact

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- Crosses many levels of design
  - Web Apps: REST, GraphQL, OpenAPI spec
  - Library interfaces
  - Class & function definitions
  - For some functions, even just the code within the function….
- An API just describes some boundary within the design process

What makes an API *good*?

- Some guidance from leaders with significant experience [Bloch 2008]
  - Easy to use and hard to misuse
  - Self documenting
  - Structured by use cases
  - Strong examples
  - Displease clients equally
  - Avoids fixed limits
  - Minimal
  - Immutable
  - Fail fast
  - …

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  - …
- Many of these can be seen as a version of the first criterion
  - That will be our goal today: easy to use & hard to misuse
  - The topic expands well beyond what we have time to cover

Let us consider a problematic API

```
bool
isFasterThanSound(double speed) {
  return speed > MACH1;
}
```

Is this easy or hard to use? Why?

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  - What are the units? Which argument is which? …

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- Ideally, only the set of appropriate values should even be possible
  - What name do we give to a set of values?

Use strong types to make APIs clear & prevent bugs

```
struct User {
  ...
};
```

```
struct Food {
  ...
};
```

```
void
feed(Food food, User user) {
[redacted]
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```

Use strong types to make APIs clear & prevent bugs

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```
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template<typename Value, typename Tag>
struct StrongAlias {
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  const Value value;
};
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using Side = StrongAlias<int, struct SideTag>;
using Angle = StrongAlias<double, struct AngleTag>;
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bool add(Element e);
void setPolicy(bool enabled);
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  - They can also force the compiler to warn when new options are unhandled!

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Phantom Types

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distanceTraveled(double speed, double time) {
  return speed * time;
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What can go wrong?

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// Miles per hour * seconds?
... = distanceTraveled(3, 5);

d1 = ...; // Meters
d2 = ...; // Miles
... = d1 + d2; // Uh oh.
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Phantom Types

- Parameterize your types by unique type names…

```
struct Meters {};
struct Miles {};
struct Seconds {};
struct Hours {};

template <typename T, typename U>
struct Speed { double speed; };

template <typename T>
struct Distance { double distance; };

template <typename T>
struct Time { double time; };
```

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struct Meters {};
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template <typename T, typename U>
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```

Speed is parameterized by time & a unit of length

Phantom Types

- Consistent units are enforced via template arguments

```
template <typename T, typename U>
Distance<T>
distanceTraveled(Speed<T,U> speed, Time<U> time) {
  return {speed.speed * time.time};
}

template <typename T>
Distance<T>
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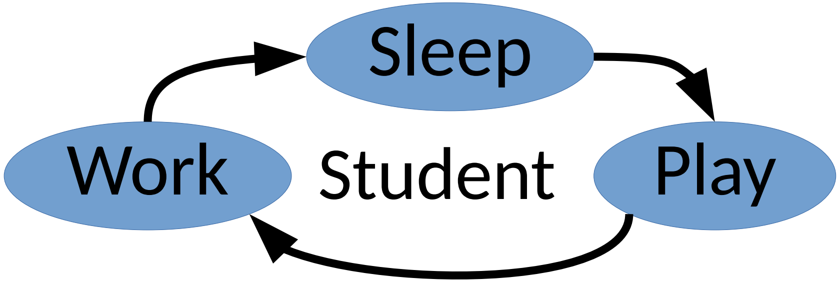
What are the trade offs for using this technique?

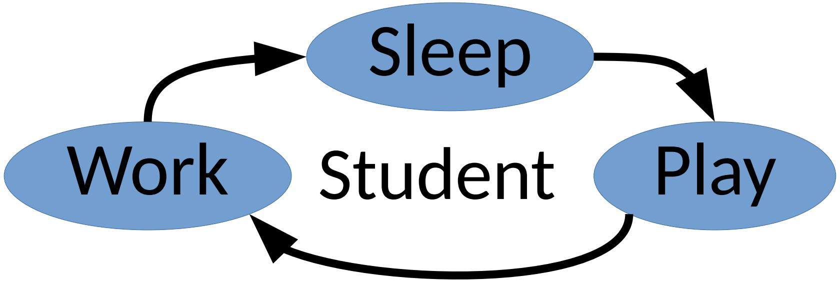
Avoiding Inconsistent State



Avoiding Inconsistent State

```
enum class CurrentState {
  SLEEP, PLAY, WORK
};
```

```
class Student {
  CurrentState state;
  uint64_t timeWorked;
};
```



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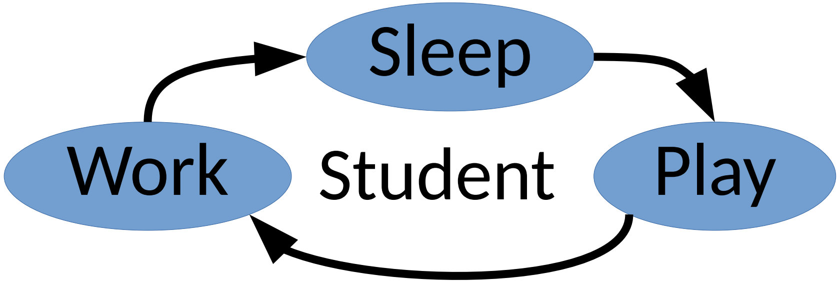

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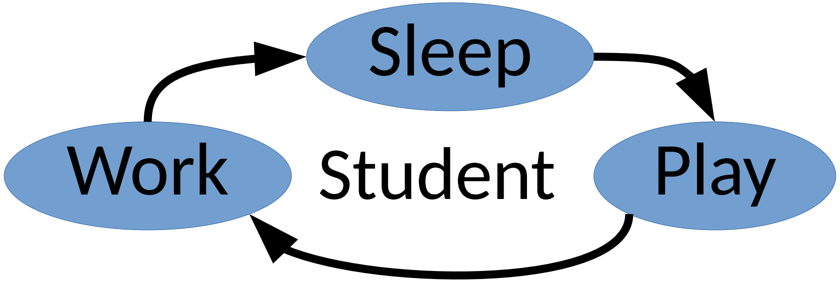

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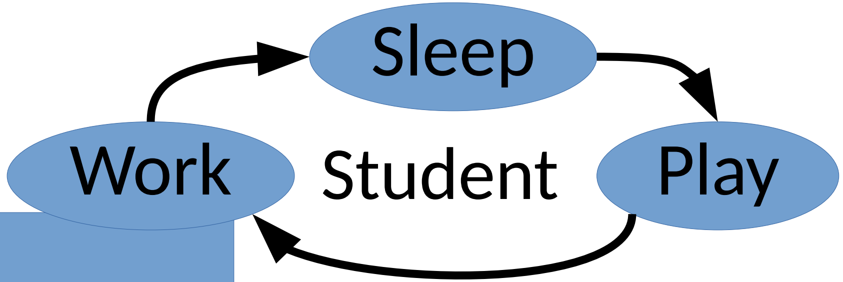

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class Student {
  unique_ptr<CurrentState> state;
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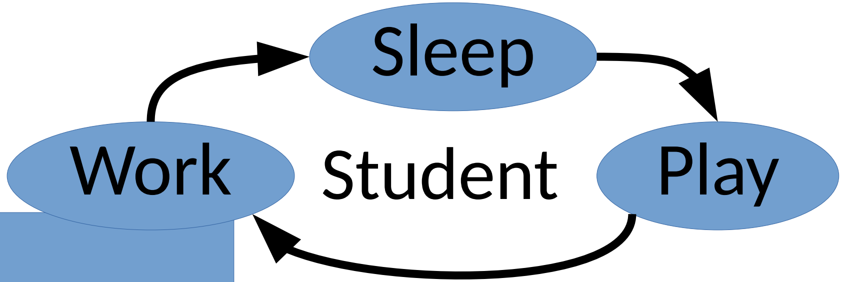

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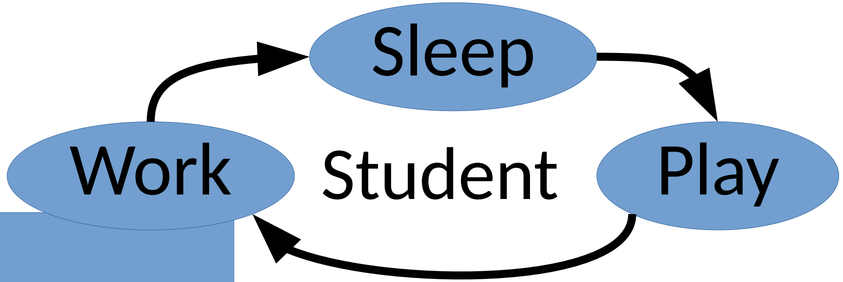

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class CurrentState {
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```
class Sleep
  : public CurrentState
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class Work
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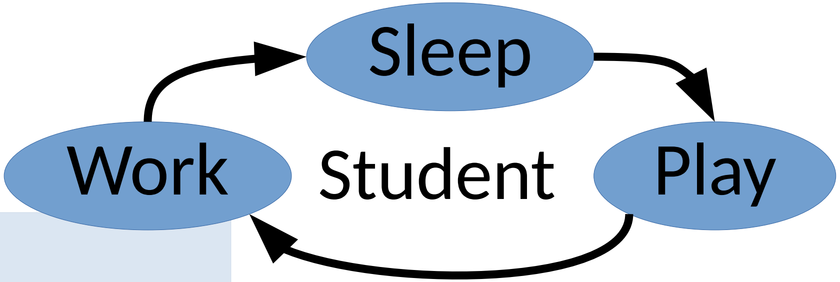

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This is part of the ***state pattern***!

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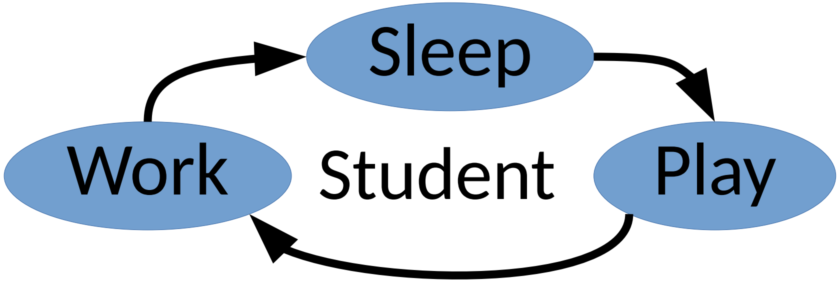

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class Student {
  struct Sleep {};
  struct Play {};
  struct Work { uint64_t timeWorked; };

  std::variant<Sleep, Play, Work> currentState;
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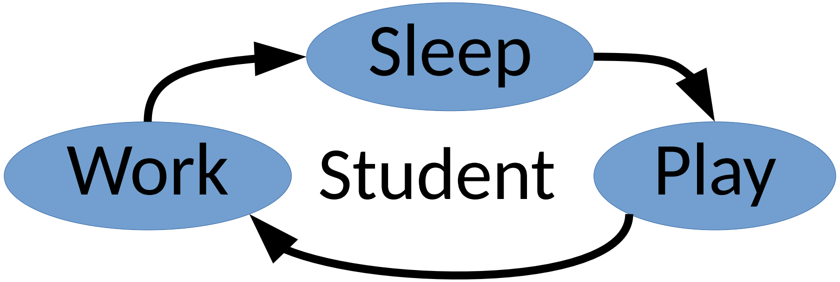

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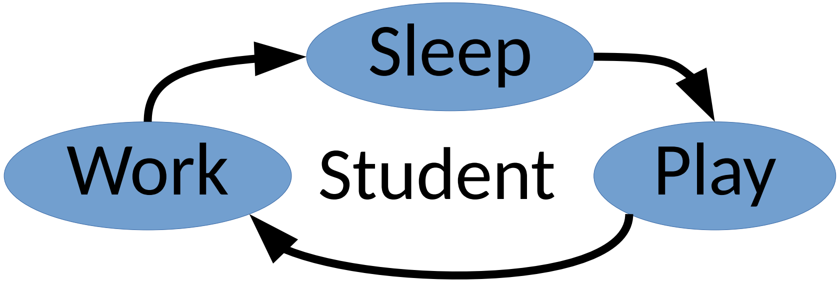

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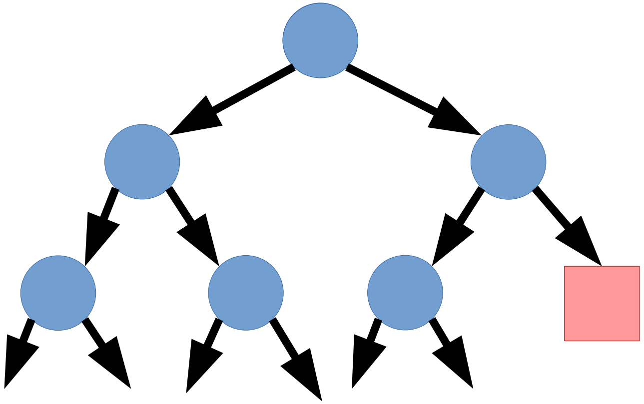

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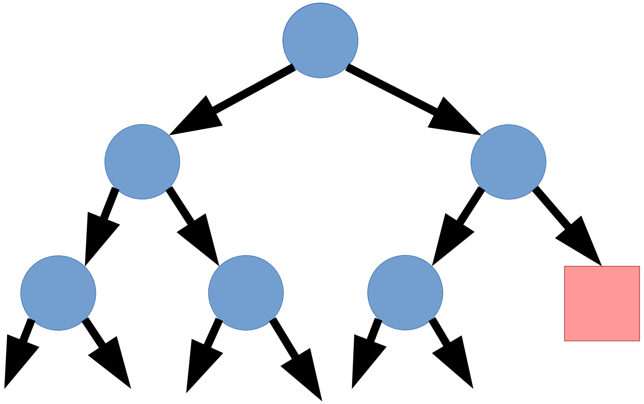
- Implicitly
  - e.g. the *null object* pattern

Null Object Pattern
Create a subtype representing an object with no information.

Any getters/methods effectively perform no-ops.



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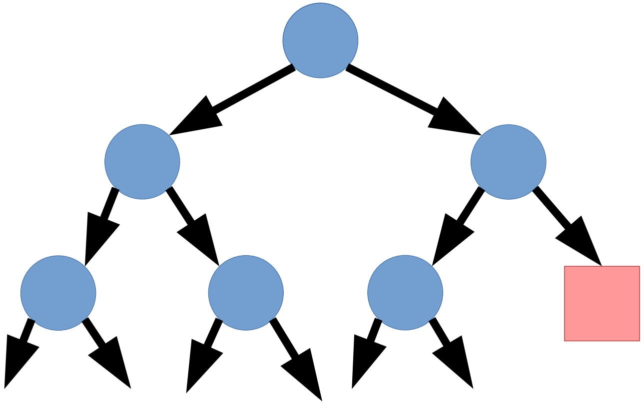
```
struct Node {
  void traverseInOrder(auto onNode);

  Node* left;
  Node* right
  int value;
};
```



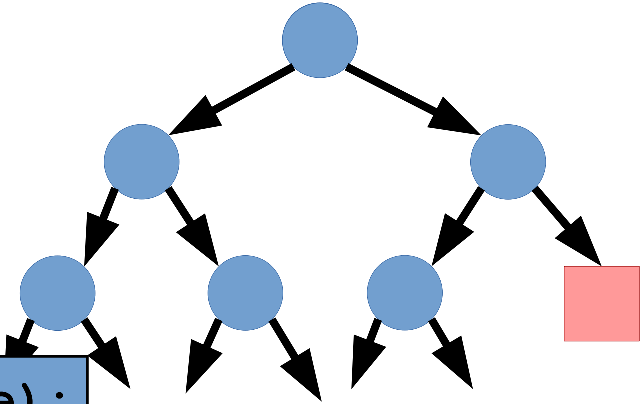
Generalize away corner cases

- Sometimes complexity comes because an abstraction is *too specific*!
  - We can generalize the interface to handle corner cases transparently
- Consider a tree that may be traversed
- Implicitly
  - e.g. the *null object* pattern

```
struct Node {
  void traverseInOrder(auto onNode);

  Node* left;
  Node* right
  int value;
};
```

```
root->traverseInOrder(printValue);
```



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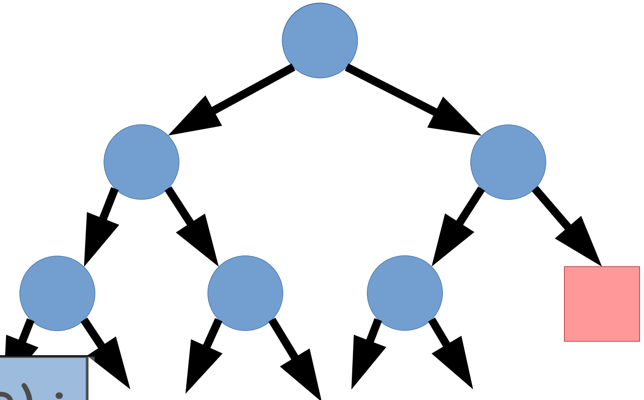

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struct Node {
  void traverseInOrder(auto onNode);

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  Node* right
  int value;
};
```

```
root->traverseInOrder(printValue);
```

```
void
Node::traverseInOrder(auto onNode) {
  if (left) left->traverseInOrder(onNode);
  onNode(this);
  if (right) right->traverseInOrder(onNode);
```

```
struct Node {
  virtual void traverseInOrder(auto onNode) = 0;
};
```

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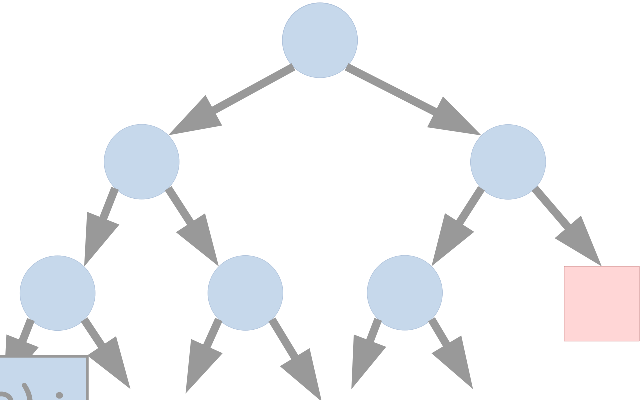

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}
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```
struct Node {
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};
```

```
struct InternalNode : public Node {
  void traverseInOrder(auto onNode) override {
    left->traverseInOrder(onNode);
    onNode(this);
    right->traverseInOrder(onNode);
  }
  int value;
};
```

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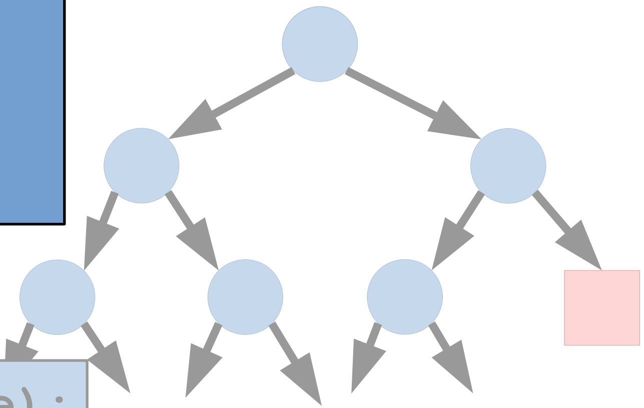

```
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  virtual void traverseInOrder(auto onNode) = 0;
};
```

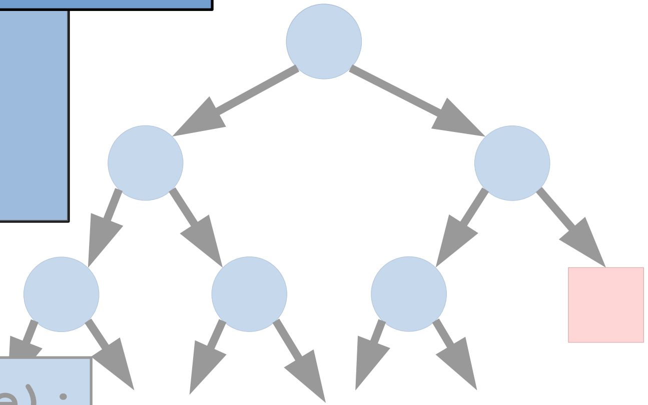
```
struct InternalNode : public Node {
  void traverseInOrder(auto onNode) override {
    right->traverseInOrder(onNode);
  }
  int value;
};
```

```
struct LeafNode : public Node {
  void traverseInOrder(auto onNode) override { }
};
```

s too specific!

sparently

e.g. the null object pattern



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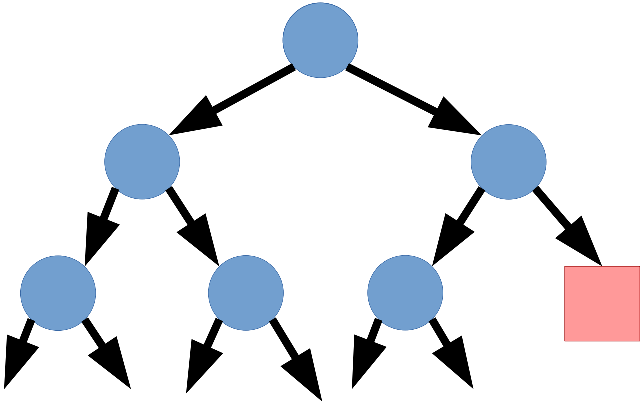

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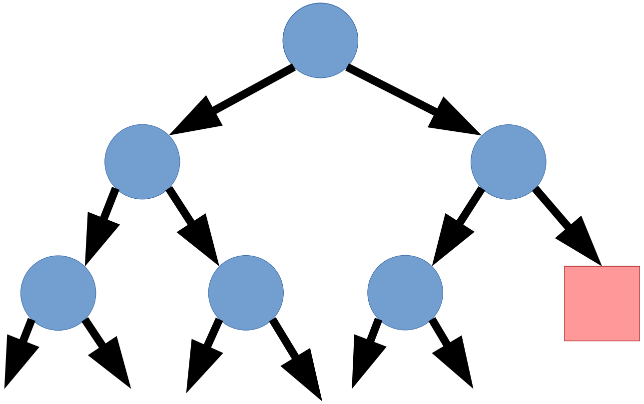

What are the trade offs?

Fluent APIs

- Fluent APIs use strong return types to enforce correct behaviors

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ComplexProcess p;
p.doThing1();
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struct ComplexProcess {
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We can make invalid usage a compilation error.

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[redacted]

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struct ComplexProcess {
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}
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  [[nodiscard]] Stage2 doStep2();
}
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struct Stage2 {
  void doStep3();
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  using nothing more than return types!

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```
InSequence dummy;
EXPECT_CALL(mockThing, foo(Ge(20)))
    .Times(2) // Can be omitted here
    .WillOnce(Return(100))
    .WillOnce(Return(200));
EXPECT_CALL(mockThing, bar(Lt(5)));
```

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```
int total = accumulate(view::iota(1)
                      | view::transform([](int x){return x*x;})
                      | view::take(10), 0);
```

[Milewski 2014]

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  - Create: z → A[z]
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- In fact, `Option` is a monad in many languages

```
std::optional<image>
get_cute_cat (const image& img) {
    auto cropped = crop_to_cat(img);
    if (!cropped) {
      return std::nullopt;
    }

    auto with_tie = add_bow_tie(*cropped);
    if (!with_tie) {
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    }

    auto with_sparkles = make_eyes_sparkle(*with_tie);
    if (!with_sparkles) {
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    return add_rainbow(make_smaller(*with_sparkles));
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sability

[Brand 2017]

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           .and_then(add_bow_tie)
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[Brand 2017]

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[Brand 2017]

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[Brand 2017]

Other more advanced topics?

- Versioning
- Performance
- Wire protocols (more like GraphQL, protobuffers, etc.)

Summary

- Try to make your APIs
  - express essential complexity of the boundary
  - hide the corner cases of the implementation

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- Try to make your APIs
    - express essential complexity of the boundary
    - hide the corner cases of the implementation
- Use types to you advantage in the process
    - Strong, expressive types
    - Fluent APIs to direct flow
    - Monadic APIs for composability while abstracting out complexity