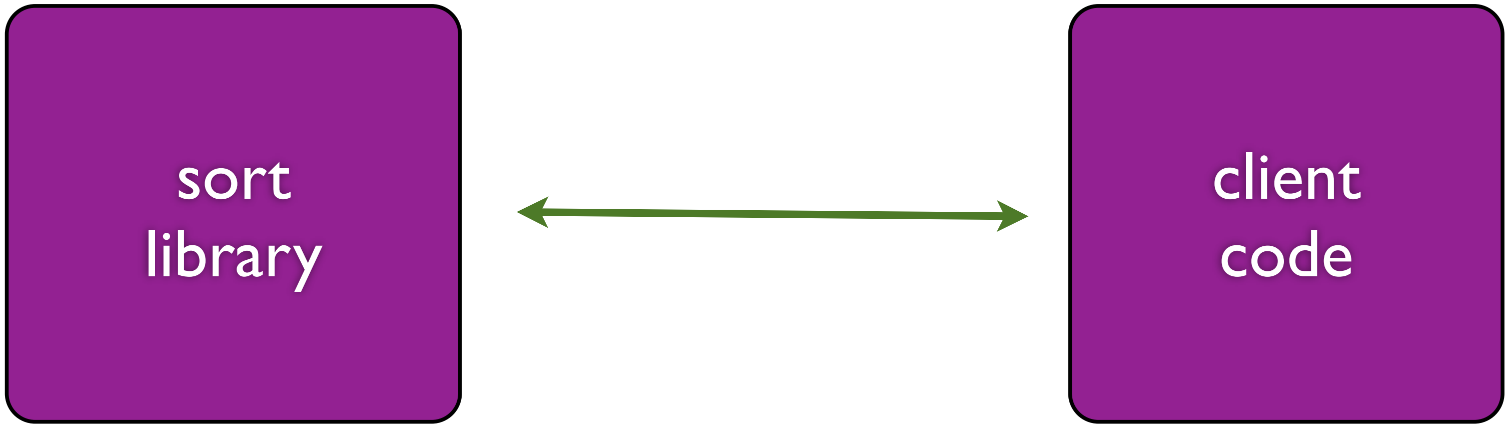
Temporal Higher-Order Contracts

Tim Disney   Jay McCarthy   Cormac Flanagan

ICFP '11



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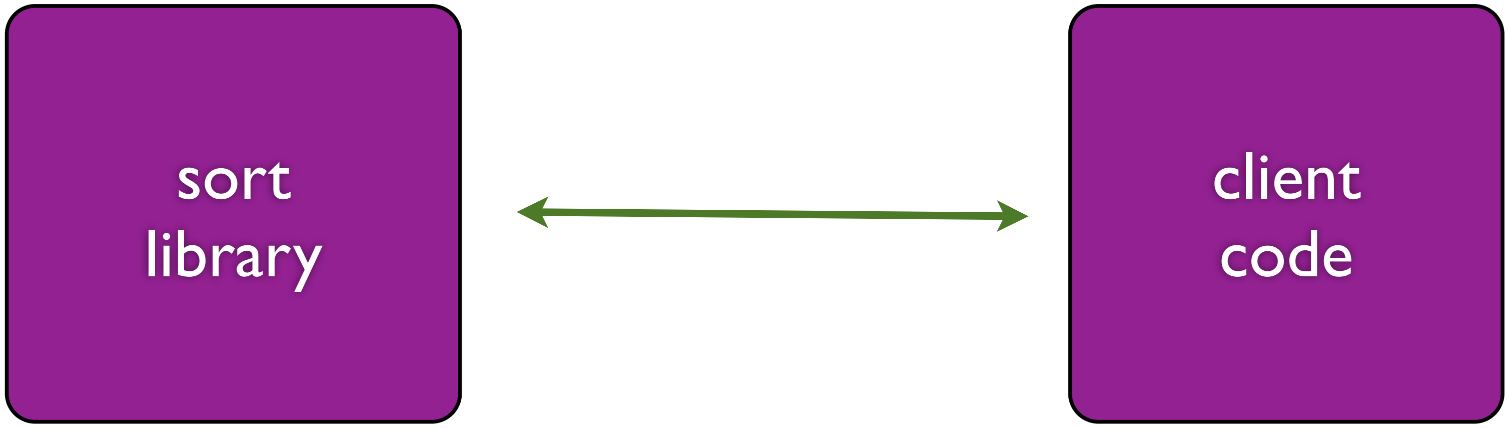
SortContract =
  sort : (List Int)
         (cmp : Int → Int → Bool)
       → (List Int)
```



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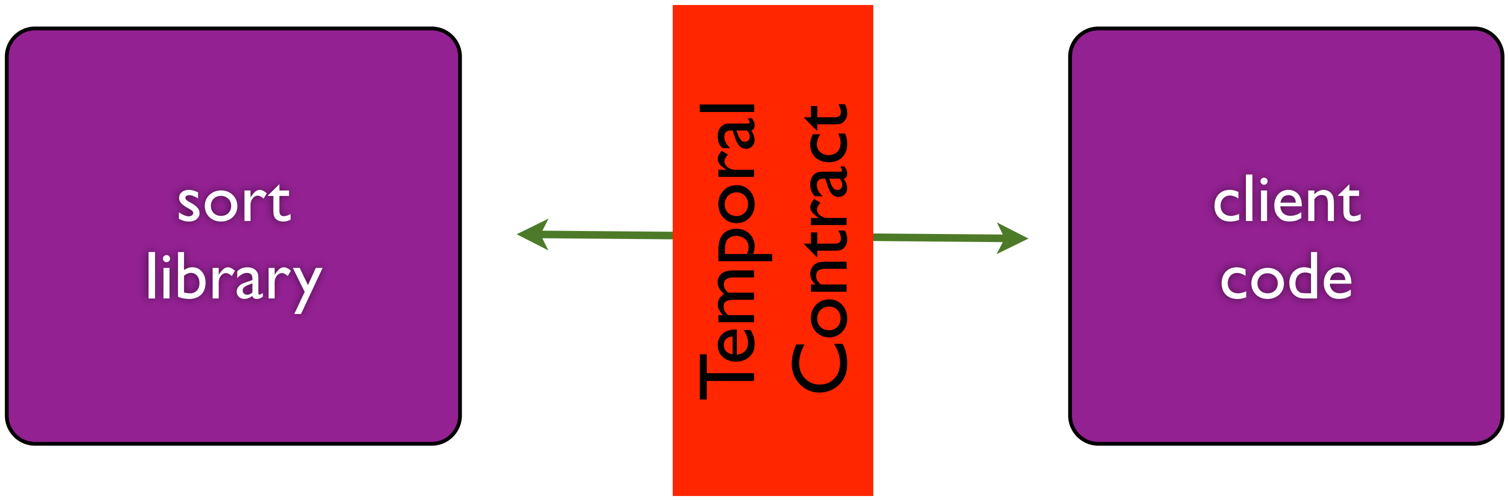
sort is not re-entrant

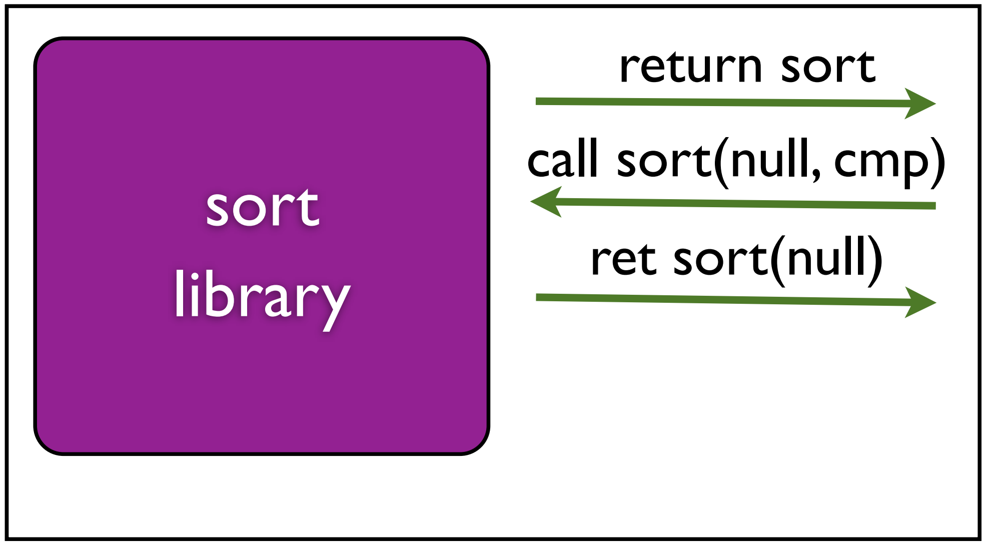
cmp is atomic

cmp is consistent



- <u>Non-interference</u>: Contracts cannot influence correct executions
- <u>Trace completeness</u>: Contracts can enforce any decidable restriction on module behavior

CSI Abstract Machine



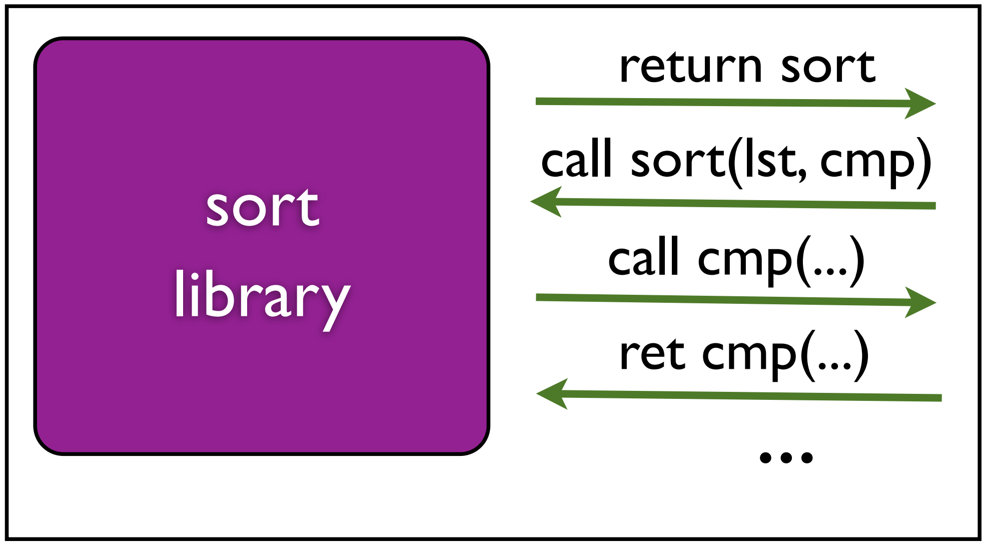
Properties of traces

- alternating send, receive
- stack-like calls & returns
- only send constants, vars
- notion of variable scope
- sends deterministic
- receive non-deterministic

CSI machine extends Control-Store machine with RPC

Semantics of module =
set of traces generated under CSI machine

CSI Abstract Machine



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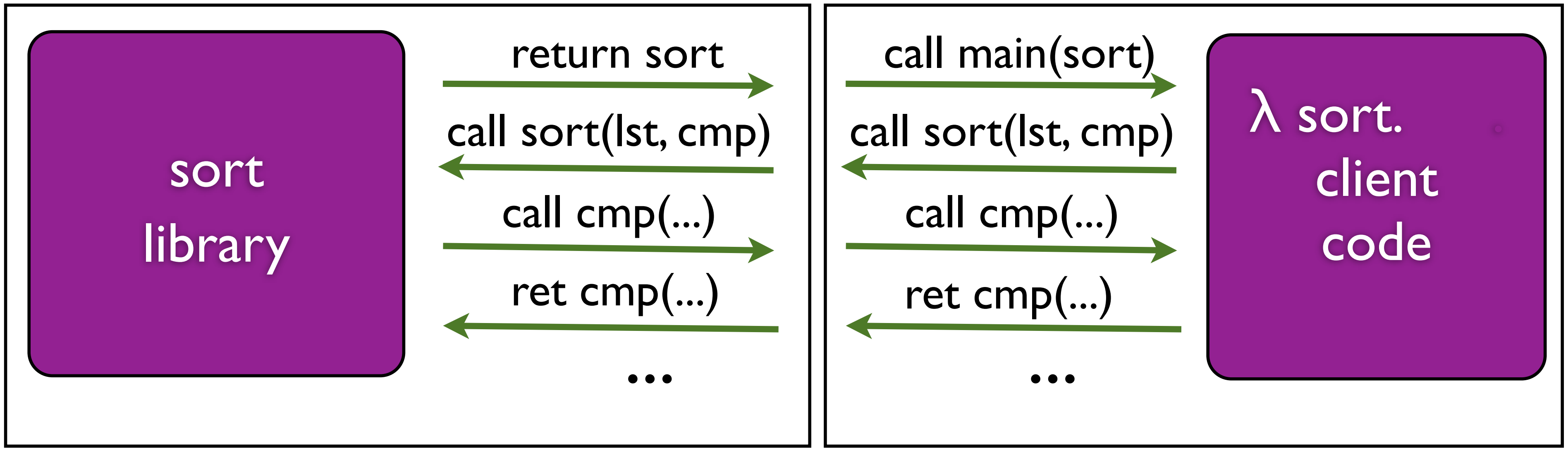
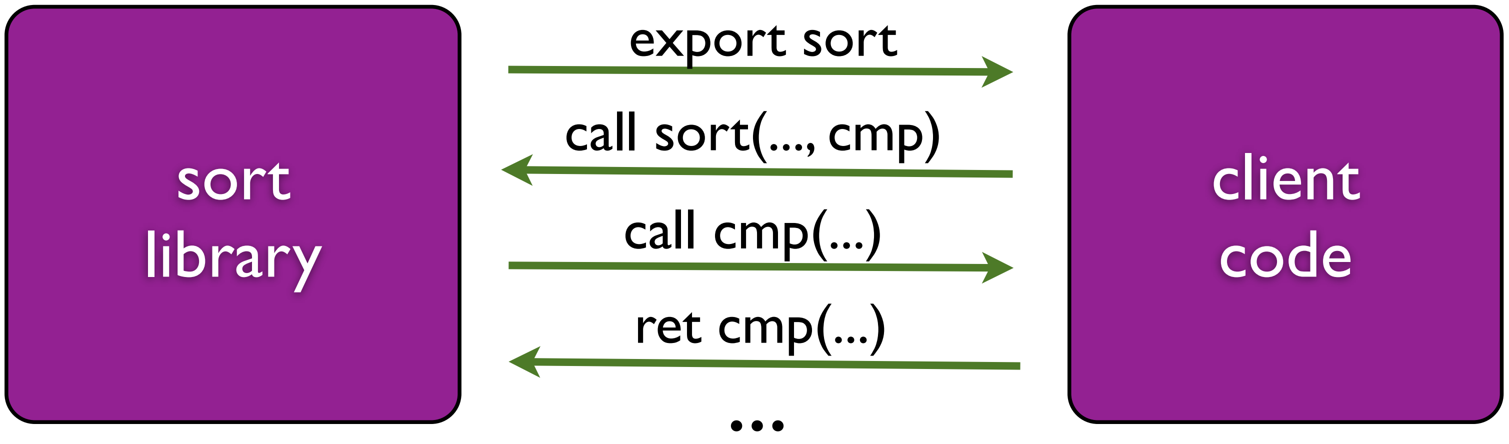
Linking CSI Machines



Module composition by linking CSI machines (matching sends with receives, etc)

Equivalent to running (client sort) on single machine

Trace completeness (without non-interference)



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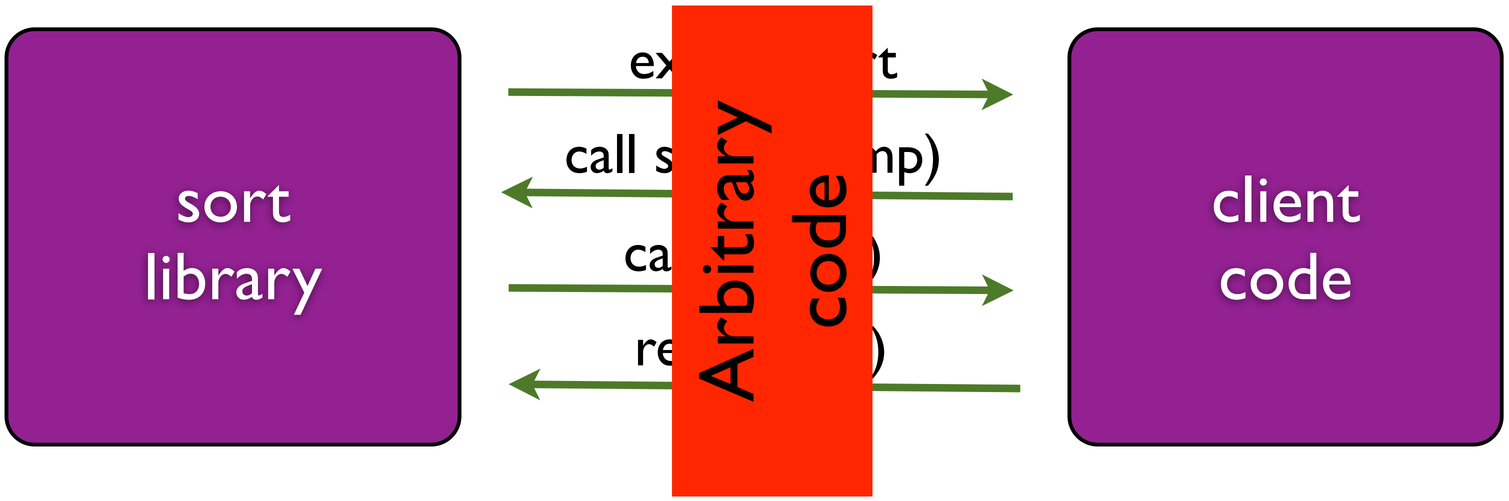
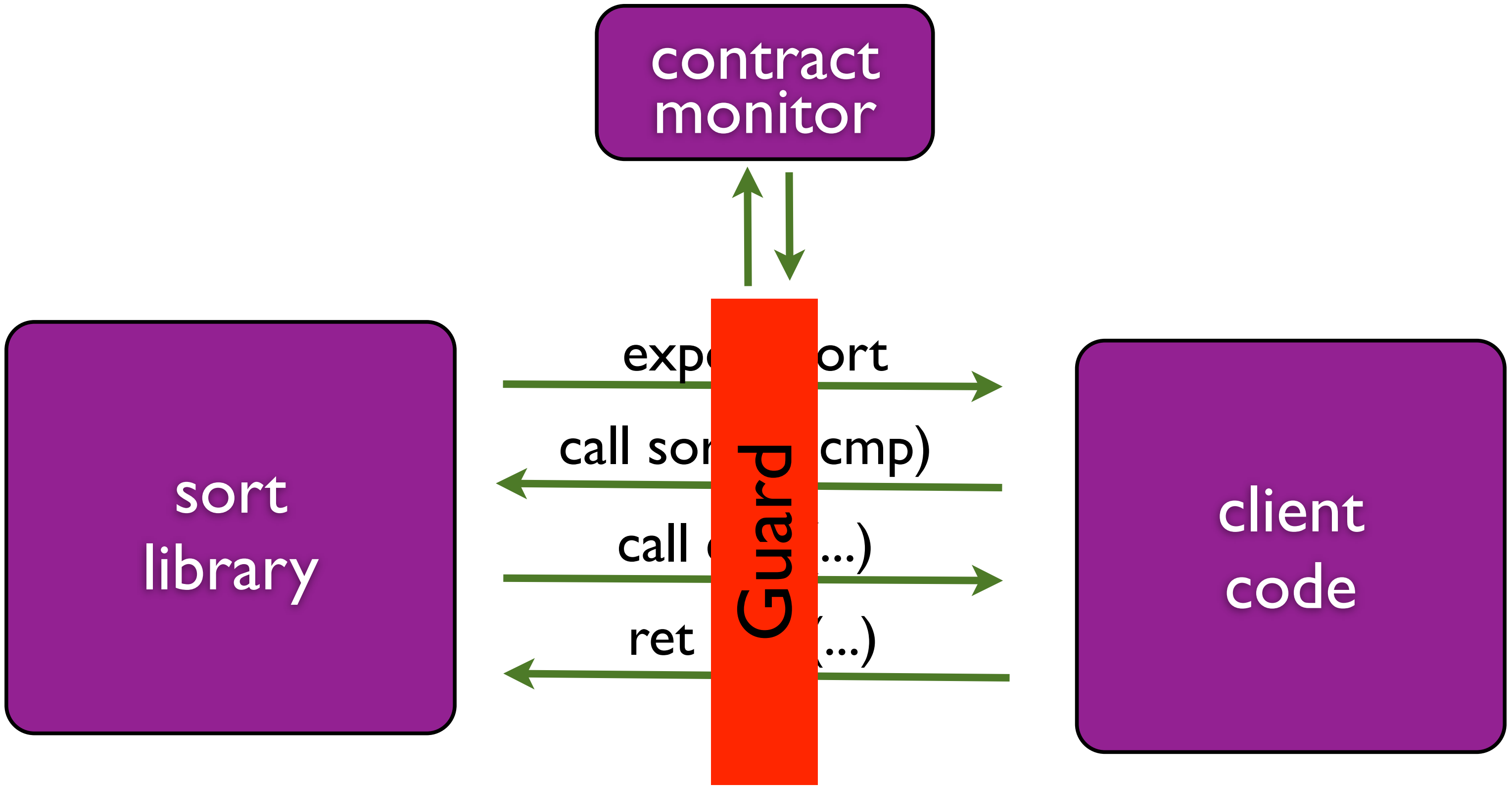
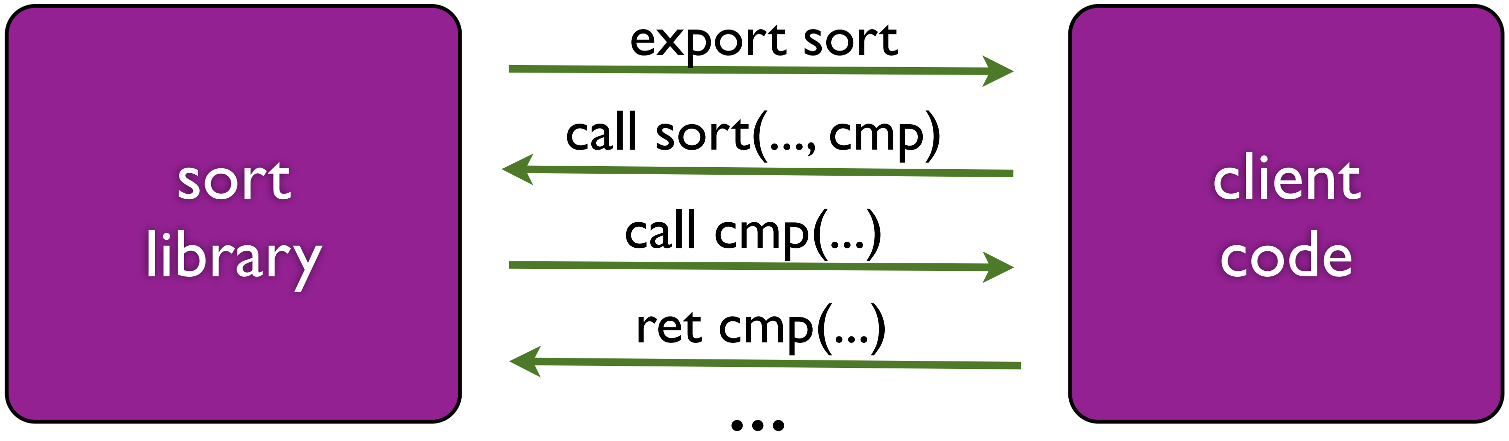


Trace completeness with non-interference



- Guard enforces non-interference without losing trace completeness
- Monitor code never sees function or refs, so cannot influence behavior except via errors



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  sort : (List Int)
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  // sort is not re-entrant
  where not ... call-sort(_) !ret-sort(_)* call-sort(_)
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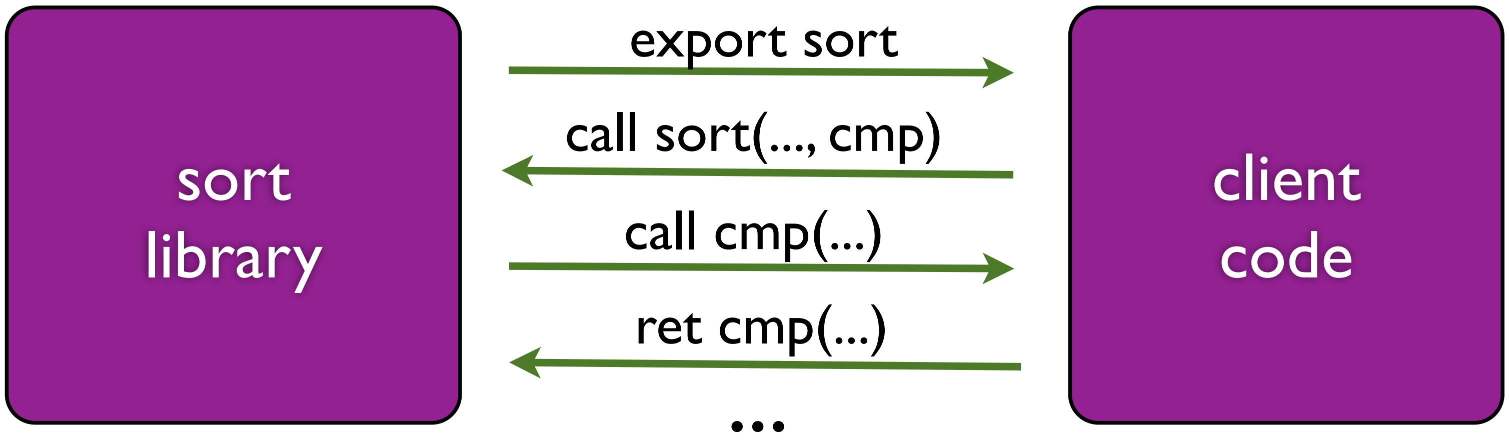

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    and not ... call-cmp(_) !ret-cmp(_)
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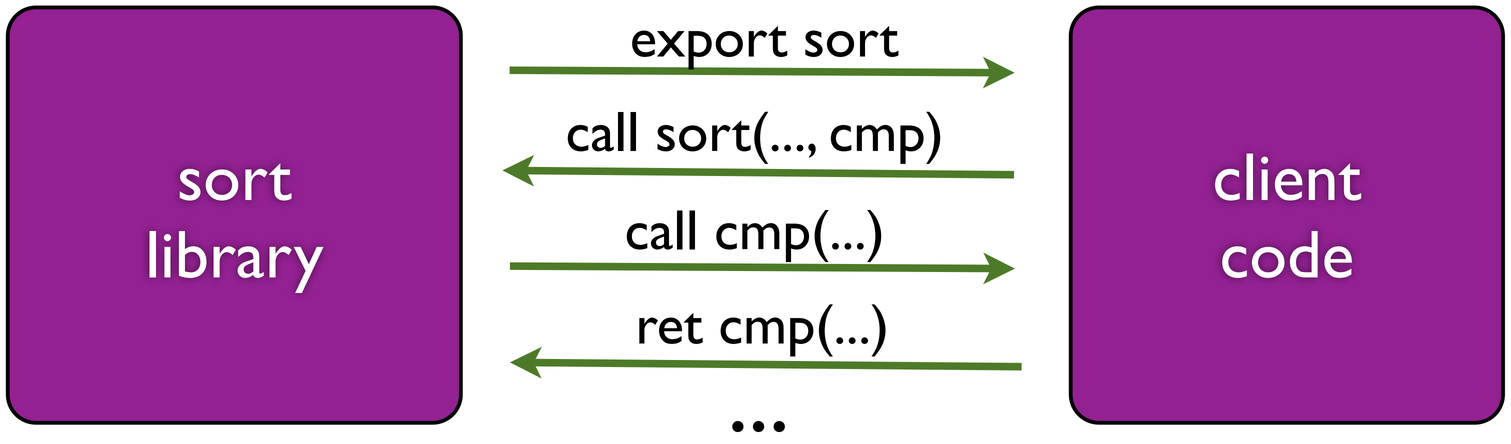

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  // sort is not re-entrant
  where not ... call-sort(_) !ret-sort(_)* call-sort(_)
  // cmp is atomic
    and not ... call-cmp(_) !ret-cmp(_)
  // cmp is consistent
    and not ... call-cmp(?x,?y)  ret-cmp(?r)
            ... call-cmp( x, y) !ret-cmp( r)
```

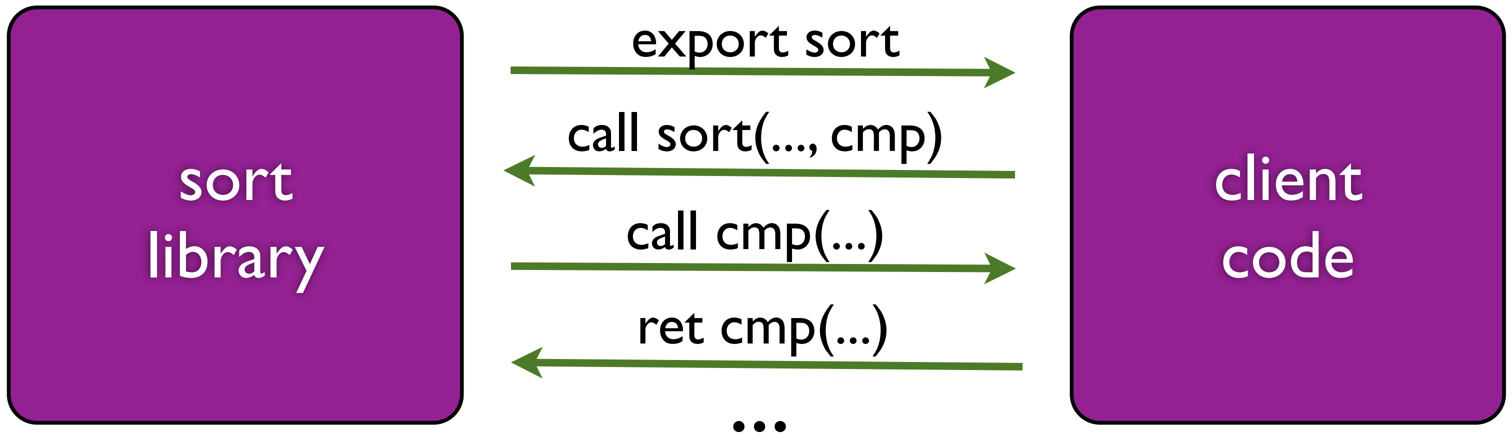

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  sort : (List Int)
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            // cmp is consistent
            where not ... call-cmp(?x,?y)  ret-cmp(?r)
                      ... call-cmp( x, y) !ret-cmp( r) )
       → (List Int)

  // sort is not re-entrant
  where not ... call-sort(_) !ret-sort(_)* call-sort(_)
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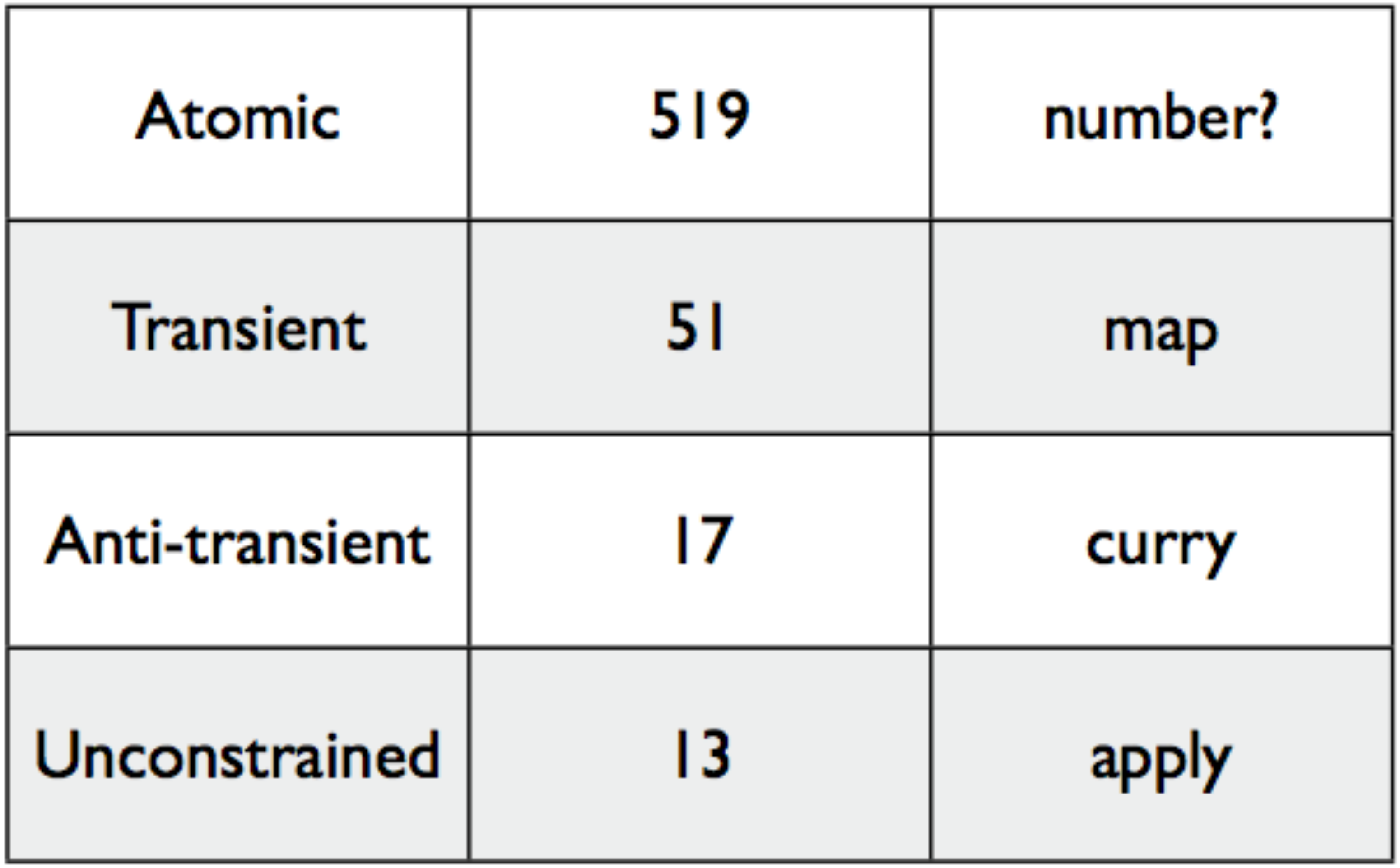
Temporal properties in the Racket Standard Library



Atomic	519	number?
Transient	51	map
Anti-transient	17	curry
Unconstrained	13	apply

Temporal Contracts for Security

- Implementation of multi-player Tic-Tac-Toe
- Each player implements `turn : Board -> Board`
- Both interactive and AI player implementations
- Players may try to cheat!
  - update board multiple times during a turn
  - overwrite previous contents on the board
- Restricted using temporal contracts
- Caught cheaters, both human and AI