Modules

Large programs benefit from more structure than a list of bindings. Breaking into parts allows separate reasoning:

• Application-level: in terms of module (in ML, structure) invariants
• Type-checking level: in terms of module types
• Implementation level: in terms of module code-generation

By providing a restricted interface (in ML, a signature), there are more equivalent implementations in terms of the interface.

Key restrictions:

• Make bindings inaccessible
• Make types abstract (know type exists, but not its definition)

SML has a much fancier module system, but we’ll stick with the basics. Abstract types are a “top-5” feature of modern languages.
Structure basics

Syntax: structure Name = struct bindings end

If \( x \) is a variable, exception, type, constructor, etc. defined in Name, the rest of the program refers to it via Name.\( x \)

(You can also do open Name, which is often bad style, but convenient when testing.)

So far, this is just namespace management, which is important for large programs, but not very interesting.
Signature basics

(For those interested in learning more, we’re doing only opaque signatures on structure definitions.)

A signature signature BLAH = sig ... end is like a type for a structure.

- Describes what types a structure provides.
- Describes what values a structure provides (and their types).

Writing structure Name :> BLAH = struct bindings end:

- Ensures Name is a legal implementation of BLAH.
- Ensures code outside of Name assumes nothing more than what BLAH provides.

Hence signatures are what really enable separate reasoning.
Signature matching

Is `Name` a legal implementation of BLAH.

- Clearly it must define everything in BLAH.
- It can define more (unavailable outside of `Name`).
- BLAH can restrict the type of polymorphic functions.
- BLAH can make types abstract.

In particular, making a datatype abstract hides the constructors, so clients have no (direct) way to create or access-parts-of values of the type.

That’s often a good thing.
Remember

A signature that “hides more” makes it easier to:

- Replace the structure implementation without breaking clients.
- Reason about how clients use the structure.

Note: The real “content” of this lecture is in the extended example.