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Type-generic lambdas

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Type-generic lambdas

ISO/IEC JTC 1/SC 22/WG14 N2924

WG21 P2306

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<https://modernc.gforge.inria.fr/>



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Policy

- *extend* the standard
 - valid code remains valid
 - new feature integrates syntactically and semantically
- fix as much requirements as possible through constraints
 - specific syntax
 - explicit constraints
- avoid new undefined behavior
 - only, if property is not (or hardly) detectable at translation time
 - or we leave design space to implementations
- don't mess with ABI
 - no changes
 - no extensions



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Current state

Proposals for C23 voted favorably by WG14

- type inference
 - **typeof**, from (type) expressions
 - **auto**, for definitions of
 - objects
 - functions
- lambdas
 - function literals
 - closures
- **defer**



Current state

Interrelationship

- **auto** needs **typeof**
- lambda needs
 - **auto** for the return type
 - **auto** for value captures
 - **auto** for variables with lambda type

Current state

Function literal (lambda without capture)

- expression
- small code snippet
- most outer identifiers are visible (compile time information)
 - types, enumeration constants, ...
 - exception: VM types
- outer identifiers are accessible
 - identifiers with static or thread storage duration (independent of linkage)
 - automatic variables are **not** accessible (only **sizeof**, **typeof**)
- can be converted to a function pointer



Current state

Closure

- *identifier capture*: access an outer variable
- *value capture*: frozen value of an expression
- *shadow capture*: frozen value of an automatic variable
- *cannot* be converted to a function pointer (needs extra state)

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Example 1: type generic lambda by using captures

```

#define MAXIMUM0 (X, Y) \
[MAXIMUM_A = (X), MAXIMUM_B = (Y)] (void) { \
    auto const a = MAXIMUM_A; \
    auto const b = MAXIMUM_B; \
    return (a < 0) \
        ? (b < 0) ? (a < b) ? b : a : b \
        : (0 < b) ? (b < a) ? a : b : a; \
} ()

```

- directly used in a function call
- no conversion to function pointer (captures!, call!)
- auxiliar names for captures
- redefinition as local variables
 - no interference with existing variables
 - respect evaluation order



Example 1: rewrite with **auto** parameters

```

#define MAXIMUM2 (X, Y)           \
  [] (auto a, auto b) {         \
    return (a < 0)               \
      ? (b < 0) ? (a < b) ? b : a : b \
      : (0 < b) ? (b < a) ? a : b : a; \
  } ((X), (Y))

```

- directly used in a function call
- no conversion to function pointer (call!)
- easier to read
- less errorprone (no auxiliary variables)



Example 2: function literal with explicit types

```

#define MAXY(X, Y) \
    [] (typeof(X) a, typeof(Y) b) { \
        return (a < 0) \
            ? (b < 0) ? (a < b) ? b : a : b \
            : (0 < b) ? (b < a) ? a : b : a; \
    }

double (*maxdd) (double, double) = MAXY(double, double);
unsigned (*maxsu) (signed, unsigned) = MAXY(signed, unsigned);

```

- conversion to function pointer, no captures
- function-like macro, but with the types as arguments
- unnatural in the context of a call

```
auto maxy = MAXY(signed, unsigned) (-1, +1);
```

- errorprone for mixed arguments

```
auto maxy = MAXY(signed, unsigned) (+1, -1); // error → UINT_MAX
```

Example 2: rewrite with **auto** parameters

```

#define MAXIMUM \
    [] (auto a, auto b) { \
        return (a < 0) \
            ? (b < 0) ? (a < b) ? b : a : b \
            : (0 < b) ? (b < a) ? a : b : a; \
    }

double (*maxdd) (double, double) = MAXIMUM;
unsigned (*maxsu) (signed, unsigned) = MAXIMUM;

```

- conversion to function pointer, no captures
- object-like macro (similar to function name)
- natural in the context of a call

```
auto maxy = MAXIMUM(-1, +1);
```

- works well for mixed arguments

```
auto maxy = MAXIMUM(+1, -1); // same
```

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Design choices

Permitted contexts

- function call
- conversion to function type

Forbidden context

- variable of lambda type
 - type generic lambdas have incomplete type

Rewrite of parameters

according to the usual rules of parameters

- array to pointer
- function to pointer



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Function pointers

provide pointers to the user

```
#define COSINUS [](auto x){ ... iteration in x ... return x; }

double (*myfunc)(double) = COSINUS;
```

future: function definitions by initialization

Several function *definitions* with different base types.

```
float      cosf(float)      = COSINUS;
double     cos (double)     = COSINUS;
long double cosl(long double) = COSINUS;
```