

# Category Theory

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# Introduction

There is an introduction to Category Theory.



# Chapter 1

## Base definitions

### 1.1 Definitions

#### 1.1.1 Object

**Definition 1.1** (Class). A class is a collection of sets (or sometimes other mathematical objects) that can be unambiguously defined by a property that all its members share.

**Definition 1.2** (Object). In category theory object is considered as something that does not have internal structure (aka point) but has a property that makes different objects belong to the same [Class](#)

**Remark 1.3** (Class of Objects). The [Class](#) of [Objects](#) will be marked as  $\text{ob}(C)$

#### 1.1.2 Morphism

Morphism is a kind of relation between 2 [Objects](#).

**Definition 1.4** (Morphism). A relation between two [Objects](#)  $a$  and  $b$

$$f_{ab} : a \rightarrow b$$

is called *morphism*. Morphism assumes a direction i.e. one [Object](#) ( $a$ ) is called *source* and another one ( $b$ ) *target*.

[Morphisms](#) have several properties. <sup>1</sup>

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<sup>1</sup>The properties don't have any proof and postulated as axioms

**Property 1.5** (Composition). If we have 3 *Objects*  $a, b$  and  $c$  and 2 *Morphisms*

$$f_{ab} : a \rightarrow b$$

and

$$f_{bc} : b \rightarrow c$$

then there exists *Morphism*

$$f_{ac} : a \rightarrow c$$

such that

$$f_{ac} = f_{bc} \circ f_{ab}$$

**Remark 1.6** (Composition). The equation

$$f_{ac} = f_{bc} \circ f_{ab}$$

means that we apply  $f_{ab}$  first and then we apply  $f_{bc}$  to the result of the application i.e. if our objects are sets and  $x \in a$  then

$$f_{ac}(x) = f_{bc}(f_{ab}(x)),$$

where  $f_{ab}(x) \in b$ .

**Property 1.7** (Associativity). The *Morphisms Composition* (*Property 1.5*) should follow associativity property:

$$f_{ce} \circ (f_{bc} \circ f_{ab}) = (f_{ce} \circ f_{bc}) \circ f_{ab} = f_{ce} \circ f_{bc} \circ f_{ab}.$$

**Definition 1.8** (Identity morphism). For every *Object*  $a$  we define a special *Morphism*  $1a : a \rightarrow a$  with the following properties:  $\forall f_{ab} : a \rightarrow b$

$$1a \circ f_{ab} = f_{ab}$$

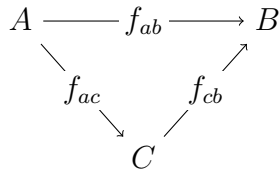
and  $\forall f_{ba} : b \rightarrow a$

$$f_{ba} \circ 1a = f_{ba}.$$

This morphism is called *identity morphism*.

**Definition 1.9** (Commutative diagram). A commutative diagram is a diagram of *Objects* (also known as vertices) and *Morphisms* (also known as arrows or edges) such that all directed paths in the diagram with the same start and endpoints lead to the same result by composition

The following diagram commutes if  $f_{ab} = f_{cb} \circ f_{ac}$ .





**Remark 1.10** (Class of Morphisms). The [Class](#) of [Morphisms](#) will be marked as  $\text{hom}(C)$

**Definition 1.11** (Monomorphism). If  $\forall g_1, g_2$  the equation

$$f \circ g_1 = f \circ g_2$$

leads to

$$g_1 = g_2$$

then  $f$  is called *monomorphism*.

**Definition 1.12** (Epimorphism). If  $\forall g_1, g_2$  the equation

$$g_1 \circ f = g_2 \circ f$$

leads to

$$g_1 = g_2$$

then  $f$  is called *epimorphism*.

### 1.1.3 Category

**Definition 1.13** (Category). A category  $\mathbf{C}$  consists of

- [Class](#) of [Objects](#)  $\text{ob}(C)$
- [Class](#) of [Morphisms](#)  $\text{hom}(C)$  defined for  $\text{ob}(C)$ , i.e. each morphism  $f_{ab}$  from  $\text{hom}(C)$  has both source  $a$  and target  $b$  from  $\text{ob}(C)$

## 1.2 Examples

There are several examples of categories that will also be used later

### 1.2.1 Set category

**Example 1.14** (Set category). *In the set category we consider a set of sets where [Objects](#) are sets and [Morphisms](#) are functions between the sets.*

**Remark 1.15** (Set vs Category). There is an interesting relation between sets and categories. In both we consider objects(sets) and relations between them(morphisms/functions).

In the set theory we can get info about functions by looking inside the objects(sets) aka use “microscope” [1]

Contrary in the category theory we initially don’t have info about object internal structure but can get it using the relation between the objects i.e. using [Morphisms](#). In other words we can use “telescope” [1] there.

**Definition 1.16** (Surjection). The function  $f : X \rightarrow Y$  is surjective (or onto) if  $\forall y \in Y, \exists x \in X$  such that  $f(x) = y$ .

**Remark 1.17** (Surjection vs Epimorphism). TBD

**Definition 1.18** (Injection). The function  $f : X \rightarrow Y$  is injective (or one-to-one function) if  $\forall x_1, x_2 \in X$ , such that  $x_1 \neq x_2$  then  $f(x_1) \neq f(x_2)$ .

**Remark 1.19** (Injection vs Monomorphism). TBD

### 1.2.2 Hask category

TBD

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