

{tikzcd}

Commutative diagrams with TikZ

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The general-purpose drawing package TikZ can be used to typeset commutative diagrams and other kinds of mathematical pictures, generating high-quality results. The present package facilitates the creation of such diagrams by providing a convenient set of macros and reasonable default settings. Familiarity with TikZ is helpful but not necessary, since the examples contained here cover the most common situations.

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Contents

1	Getting started	1
1.1	Creating a diagram	2
1.2	Inserting arrows	2
1.3	Changing arrow tips	3
1.4	Alternative syntax for arrows	4
1.5	Usage in plain T _E X	5
1.6	Usage in ConT _E Xt	5
2	Controlling the appearance of diagrams	5
2.1	General options	6
2.2	Global options for arrows	7
2.3	Absolute placement of arrows	8
2.4	Phantom arrows	9
2.5	Fine-tuning the placement of arrows	9
2.6	Three-dimensional diagrams	10
2.7	Options for labels	11
3	Advanced usage	11
3.1	Internals of tikzcd and the arrow commands	12
3.2	Tweaking to paths	12
3.3	Drawing diagrams directly with TikZ	13
3.4	Issues with active characters	13
4	Additional goodies	14
4.1	The <code>asymmetrical rectangle</code> shape	14
4.2	Reading font parameters	15
4.3	Computer Modern arrow tips	15
4.4	Glyph arrow tips	15
	Index	17

1 Getting started

To load this package in L^AT_EX, type

```
\usepackage{tikz-cd}
```

or load TikZ and then type

```
\usetikzlibrary{cd}
```

This package is compatible with other T_EX formats as well. See §1.5 and §1.6.

1.1 Creating a diagram

The basic tool to create a commutative diagram is the following environment.

```
\begin{tikzcd}[\langle options \rangle]
  \langle environment contents \rangle
\end{tikzcd}
```

The environment contents should describe a matrix, as in L^AT_EX's familiar `{tabular}` environment. The optional argument $\langle options \rangle$ may be used to modify the appearance of the diagram. Any of the customization keys described in this manual, as well as those originally provided by TikZ, can be used here. Arrows between matrix entries can be created with the `\arrow` command described below.

Everything inside `{tikzcd}` is typeset in math mode, but you will probably want to use it inside an `{equation}` environment or `\[... \]`, so that the diagram is placed on a new line and centered.

It is important to note that DVI viewers will not display diagrams correctly. It is necessary to convert the DVI file to PDF or PS format—or, even better, use a tool that generates PDF files directly, such as `pdflatex`.

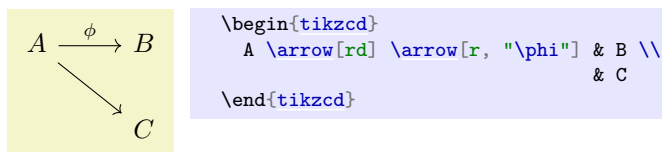
1.2 Inserting arrows

Inside the `{tikzcd}` environment, the following synonymous commands are provided to produce arrows.

```
\arrow[\langle options \rangle]
\ar[\langle options \rangle]
```

Here, $\langle options \rangle$ is a comma-separated list of options which can be used to specify the arrow target, add labels, change arrow tips, and perform additional modifications.

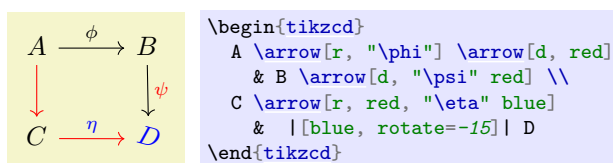
The arrow target can be specified by a direction parameter, which consists of a string of characters `r`, `l`, `d`, `u` (standing for right, left, down and up). Labels can be placed on an arrow by means of the quotes syntax, described in detail in the PGF manual [2, §17.10.4]. Notice the use of `"\phi"` in the example below.



To further modify the appearance of an arrow, note that $\langle options \rangle$ may contain any key that can be passed to TikZ's `\path` command. Similarly, a label can receive additional options via the syntax

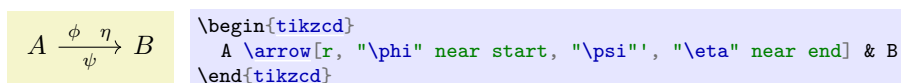
`"\langle label text \rangle" \langle label options \rangle`.

Both $\langle label text \rangle$ and $\langle label options \rangle$ need to be enclosed in curly braces if they contain commas.

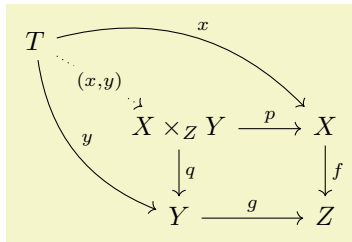


The example above also showcases one of the possible ways to pass special options to a TikZ matrix node. See the PGF manual [2, §20] for more information.

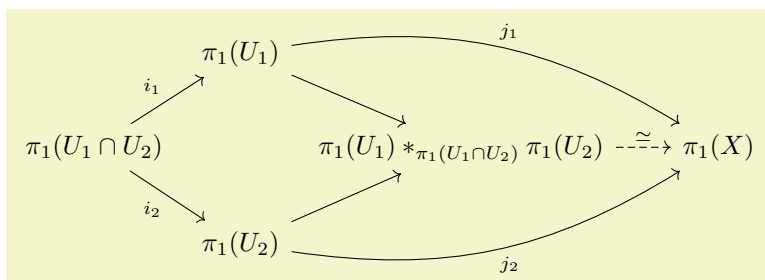
Arrows can have an arbitrary number of labels, by repeated use of arguments in quotes. The example below shows how to control the positioning of labels. Notice in particular that an apostrophe as $\langle label option \rangle$ causes the label to be placed on the opposite side of the arrow.



We provide two real-life examples.



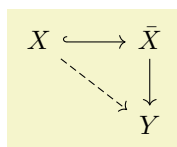
```
\begin{tikzcd}
T
\arrow[dr, bend left, "x"]
\arrow[ddr, bend right, "y"]
\arrow[dr, dotted, "{(x,y)}" description] & & \\
& X \times_Z Y \arrow[r, "p"] \arrow[d, "q"] & X \arrow[d, "f"] \\
& Y \arrow[r, "g"] & Z
\end{tikzcd}
```



```
\begin{tikzcd}[column sep=tiny]
& \pi_1(U_1) & & \\
\pi_1(U_1 \cap U_2) & \nearrow^{i_1} & & \\
& & \pi_1(U_1) *_{\pi_1(U_1 \cap U_2)} \pi_1(U_2) & \dashrightarrow^{\simeq} \pi_1(X) \\
& \searrow_{i_2} & & \\
& \pi_1(U_2) & & \\
& & \nearrow_{j_2} & \\
& & & \searrow_{j_1}
\end{tikzcd}
```

1.3 Changing arrow tips

A set of `\arrow` options is provided to create different kinds of arrows. Some of these options have a short descriptive name, such as `hook`, and others are named after \TeX arrow-producing commands (without a “ \backslash ”), like `dashrightarrow`.



```
\begin{tikzcd}
X \arrow[r, hook] \arrow[dr, dashrightarrow]
& \bar{X} \\
& Y
\end{tikzcd}
```

The following list shows all available arrow types (each of them is a style key located in `/tikz/commutative diagrams`).

Basic arrows

- to head yields \rightsquigarrow
- rightarrow yields \longrightarrow
- leftarrow yields \longleftarrow
- leftrightharrow yields \longleftrightarrow
- Rightarrow yields \Longrightarrow
- Leftarrow yields \Longleftarrow
- Leftrightharrow yields \Leftrightarrow

Arrows from bar

- maps to yields \mapsto
- mapsto yields \mapsto
- mapsfrom yields \longleftarrow
- Mapsto yields \mapsto
- Mapsfrom yields \longleftarrow

Arrows with hook

hook yields $\leftarrow\times$
hook' yields $\leftarrow\times$
hookrightarrow yields $\rightarrow\times$
hookleftarrow yields $\leftarrow\times$

Arrows with tail

tail yields $\rightarrow\times$
rightarrowtail yields $\rightarrow\times$
leftarrowtail yields $\leftarrow\times$

Two-headed arrows

two heads yields $\times\leftrightarrow$
twoheadrightarrow yields \leftrightarrow
twoheadleftarrow yields \leftrightarrow

Harpoons

harpoon yields $\times\rightarrow$
harpoon' yields $\times\rightarrow$
rightharpoonup yields \rightarrow
rightharpoondown yields \rightarrow
leftharpoonup yields \leftarrow
leftharpoondown yields \leftarrow

Dashed arrows

dashed yields $\times\text{---}\times$
dashrightarrow yields $\text{---}\rightarrow$
dashleftarrow yields $\leftarrow\text{---}$

Squiggly arrows

squiggly yields $\times\rightsquigarrow\times$
rightsquigarrow yields \rightsquigarrow
leftsquigarrow yields \leftsquigarrow
leftrightsquigarrow yields $\rightsquigarrow\leftsquigarrow$

Non-arrows

no head yields $\times\text{---}$
no tail yields $\text{---}\times$
dash yields ---
equal yields ===

A gray cross (\times) in the samples above indicates that the corresponding tip is kept unchanged. This allows several arrow styles to be superimposed.

$A \rightarrow\text{---}\rightarrow B$	<pre>\begin{tikzcd} A \arrow[r, tail, two heads, dashed] & B \end{tikzcd}</pre>
----------------------------------------	-------------------------------------------------------------------------------------

1.4 Alternative syntax for arrows

The following forms of the arrow command were used before the appearance of the quotes syntax for labels, and now may seem somewhat convoluted. They are nonetheless still available for backwards compatibility.

`\arrow[options]{direction}{labels}`

Here, *direction* is a string containing the characters r, l, d, u and is used to determine the arrow target. Alternatively, you can specify an explicit matrix cell by replacing *direction* with something of the form *row number*-*column number*, or the name of a node. The trailing *labels* can be the empty string or of the form

`[label options]{label text}{more labels}`.

The equivalent command `\var` can also be used in this form. Here is an example.

$\begin{array}{ccc} A & \xrightarrow{\phi \quad \psi} & B \\ \downarrow & & \downarrow \xi \\ C & \xrightarrow{\eta} & D \end{array}$	<pre>\begin{tikzcd} A \arrow[d] \arrow[r][near start]{\phi}[near end]{\psi} & B \arrow[red]{d}{\xi} \\ C \arrow[red]{r}[blue]{\eta} & D \end{tikzcd}</pre>
---------------------------------------------------------------------------------------------------------------------------------------	--------------------------------------------------------------------------------------------------------------------------------------------------------------------

There are further shortened forms:

`\rar[options]{labels}`
`\lar[options]{labels}`
`\dar[options]{labels}`
`\uar[options]{labels}`
`\drar[options]{labels}`

```
\urar[<options>]<labels>
\dlar[<options>]<labels>
\ular[<options>]<labels>
```

The first one is equivalent to

```
\arrow[<options>]{r}<labels>
```

and the other ones work analogously.

1.5 Usage in plain T_EX

To use this package in plain T_EX, load TikZ and the cd library by saying

```
\input tikz.tex
\usetikzlibrary{cd}
```

The {tikzcd} environment should then be replaced by the following:

```
\tikzcd[<options>]
  <environment contents>
\endtikzcd
```

All other functions of this library work as described in this manual without change.

1.6 Usage in ConT_EXt

To use this package in ConT_EXt, load TikZ and then the cd library by saying

```
\usemodule[tikz]
\usetikzlibrary[cd]
```

The {tikzcd} environment should then be replaced by the following:

```
\starttikzcd[<options>]
  <environment contents>
\stoptikzcd
```

Moreover, you may replace the column and row separators &, \\\ by their ConT_EXt analogues \NC, \NR. However, you should use \NC only *between* cells, and not before the first column or after the last column, as in usual ConT_EXt tables. Similarly, \NR should be used only between rows.

All other functions of this library work as described in this manual without change.

2 Controlling the appearance of diagrams

This section describes a number of customization keys defined by this package. All keys are located in the path /tikz/commutative diagrams. Options passed to {tikzcd} or \arrow are searched for in that path, and, if not found there, in /tikz. To set options globally, it is convenient to use the following command.

```
\tikzcdset{<options>}
```

Executes *<options>* in the path /tikz/commutative diagrams.

Besides the keys described in this manual, numerous TikZ parameters can affect the appearance of a diagram. However, only a few of them (namely those appearing in `every diagram`, `every cell`, `every arrow`, and `every label` below) are reinitialized when {tikzcd} is called. This means that modifying a certain TikZ parameter globally may or may not affect the output of {tikzcd}.

We also point out that besides the options and styles provided by this package, several keys defined by TikZ are useful for arrows. Some examples are `dashed`, `dotted`, and its relatives, `line width=<dimension>`, `color=<color>`, `bend right`, `bend left`, `in=<angle>`, `out=<angle>`, `loop`, etc. See the PGF manual [2, §15.3.1 and §74]. Likewise, TikZ provides several keys that are useful for labels, such as `above`, `below`, `left`, `right`, `swap` (which makes the label be placed on the right side of the arrow, relative to its direction), `sloped`, `pos=<fraction>`, `near start`, `near end`, `inner sep=<dimension>`, `font=`, `text width=<dimension>`, etc. See the PGF manual [2, §17, esp. §17.8].

2.1 General options

`/tikz/commutative diagrams/every diagram` (style, no value)

This style is applied to every `{tikzcd}` environment. Initially, it contains the following:

```
row sep=normal,
column sep=normal,
/tikz/baseline=Opt
```

The `baseline=Opt` setting is used to make equation numbers be placed correctly (as an exception, one-row diagrams are anchored at their matrix base, which is exactly what you want).

`/tikz/commutative diagrams/diagrams=<options>` (no default)

This key appends `<options>` to the style `every diagram`.

`/tikz/commutative diagrams/every matrix` (style, no value)

This style is applied to the TikZ matrix created internally by `{tikzcd}`. Initially, it contains the following:

```
/tikz/inner sep=Opt
```

`/tikz/commutative diagrams/every cell` (style, no value)

This style is applied to every TikZ matrix cell created by `{tikzcd}`. Initially, it contains the following:

```
/tikz/shape=asymmetrical rectangle,
/tikz/inner xsep=1ex,
/tikz/inner ysep=0.85ex
```

The `asymmetrical rectangle` shape is described in §4.1. The `inner xsep`, `inner ysep` options determine the spacing between a diagram entry and any arrows reaching it.

`/tikz/commutative diagrams/cells=<options>` (no default)

This key appends `<options>` to the style `every cell`.

`/tikz/commutative diagrams/row sep=<size>` (no default)

This key acts as a frontend to TikZ's `/tikz/row sep` key. If the key

```
/tikz/commutative diagrams/row sep/<size>
```

stores a `<value>`, then it is read and `/tikz/row sep=<value>` is set. If the key above is not initialized, then `<size>` is presumed to be a dimension, and `/tikz/row sep=<size>` is set.

The initially available sizes, and their values, are the following:

<code>tiny</code>	<code>small</code>	<code>scriptsize</code>	<code>normal</code>	<code>large</code>	<code>huge</code>
0.45 em	0.9 em	1.35 em	1.8 em	2.7 em	3.6 em

Notice that setting, say, `row sep=1cm` globally with `\tikzcdset` will have no effect, since the `row sep` option is re-set at the beginning of each diagram. To make all diagrams have `row sep` equal to 1 cm, you can modify the meaning of `normal` by saying

```
\tikzcdset{row sep/normal=1cm}.
```

You can also create new sizes, but note that PGF requires new keys to be initialized explicitly. For example, to create a size `my size`, meaning 1 ex, you should use

```
\tikzcdset{row sep/my size/.initial=1ex}.
```

`/tikz/commutative diagrams/column sep=<size>` (no default)

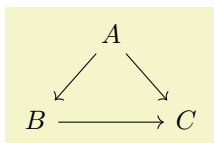
This works analogously to the `row sep` key above. The sizes available initially are the following:

<code>tiny</code>	<code>small</code>	<code>scriptsize</code>	<code>normal</code>	<code>large</code>	<code>huge</code>
0.6 em	1.2 em	1.8 em	2.4 em	3.6 em	4.8 em

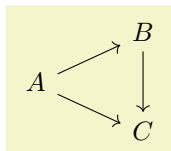
`/tikz/commutative diagrams/sep=<size>` (no default)

This key sets `row sep=<size>`, `column sep=<size>`.

In the examples below, the triangular diagrams would look too wide or too tall if the column or row separation were not set appropriately.



```
\begin{tikzcd}[column sep=small]
 & A & \\
 B \arrow{rr} & & C \\
\end{tikzcd}
```



```
\begin{tikzcd}[row sep=tiny]
 & B & \\
 A \arrow{ur} \arrow{dr} & & \\
 & C & \\
\end{tikzcd}
```

Section 20.3.2 of the PGF manual [2] contains further details on the spacing of matrix cells.

`/tikz/commutative diagrams/cramped` (style, no value)

By default, a generous amount of white space is added around diagram cells, which is appropriate for large, displayed diagrams. The present style removes some of this extra white space, and is intended for smaller diagrams that should blend with the surrounding text, or very wide material that wouldn't fit the page otherwise.

The picture below shows the (somewhat subtle) difference between the cramped and the non-cramped styles.

This $A \longrightarrow B$ is a regular diagram.
 This $A \rightarrow B$ is a cramped diagram.
 This $A \to B$ is just a formula.

```
This \begin{tikzcd} A \arrow[r] & B \end{tikzcd} is a regular diagram.\\
This \begin{tikzcd}[cramped, sep=small] A \arrow[r] & B \end{tikzcd} is a cramped diagram.\\
This $A \to B$ is just a formula.
```

Keep in mind that while there are some legitimate uses for `{tikzcd}` diagrams on inline formulas, standard L^AT_EX constructs such as `\overset` and `\xrightarrow` are often sufficient and should be preferred.

`/tikz/commutative diagrams/math mode=<boolean>` (default true)

This key determines whether or not the contents of a diagram are typeset in math mode. If set globally or diagram-wise, it affects both the diagram entries and arrow labels. If used with `\arrow`, it affects only its labels.

`/tikz/commutative diagrams/background color=<color>` (no default, initially white)

This key stores the name of a color, and is read by styles that fill the background, such as `description` and `crossing over`. It does not cause the background of diagrams to be filled.

2.2 Global options for arrows

`/tikz/commutative diagrams/every arrow` (style, no value)

This style is applied to every `\arrow`. Initially, it contains the following:

```
/tikz/draw,
/tikz/line width=rule_thickness,
rightarrow
```

`/tikz/commutative diagrams/arrows=<options>` (no default)

This key appends `<options>` to the style `every arrow`.

`/tikz/commutative diagrams/arrow style=style` (no default)

This key determines which collection of arrow tips is used by the arrow tip selection styles listed in §1.3. The initial setting is suitable for documents using the Computer Modern font at any size. The available choices for *style* are:

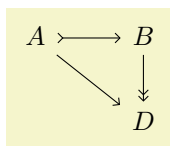
Latin Modern A small variant of the initial settings, intended for documents using the Latin Modern font at any size.

math font This setting uses the Glyph meta arrow tip described in §4.4.

tikz This setting uses the arrow tips defined in TikZ's `arrows.meta` library. It honors the option `/tikz/`.

This key is usually invoked in the document preamble, and should be set only once.

If you are using a font different from Computer Modern or Latin Modern, you may find the best results by selecting the `math font` style. As detailed in §4.4, this is not guaranteed to work perfectly with all fonts, but gives good results in many cases. If the `math font` style gives unsatisfactory results, you can try selecting the `tikz` style, and setting `/tikz/` to the value that best matches your font (among those shown in [2, §16.5]).



```
% in preamble
\tikzcdset{
  arrow style=tikz,
  diagrams={>={Straight Barb[scale=0.8]}}
}

% in document body
\begin{tikzcd}
A \arrow[r, tail] \arrow[rd] & B \arrow[d, two heads] \\
& & D
\end{tikzcd}
```

2.3 Absolute placement of arrows

The usual behavior of `\arrow` is to produce an arrow starting at the diagram entry where the command appears, and ending at an entry whose location is specified relative to that. The following keys override this behavior, allowing source and target to be selected explicitly.

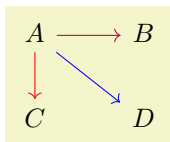
`/tikz/commutative diagrams/from=argument` (no default)

If *argument* is of the form *row number*-*column number*, or if it is a string of characters `r`, `l`, `d`, `u`, this key sets the arrow source to be the corresponding cell in the diagram matrix. Otherwise, it assumes the argument is the name of a node and sets the arrow source to *argument*.

`/tikz/commutative diagrams/to=argument` (no default)

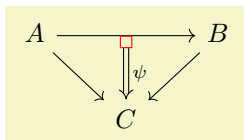
Similar to `from`, but refers to the arrow target.

Recall that it is possible to give a specific entry of a TikZ matrix a name by using the `|[options]` syntax, as done for entry *C* in the example below. You must be careful not to create nodes whose name contains only the characters `l`, `r`, `u`, `d` if you want to refer to them using `from` or `to`. The following illustrates several different uses of these keys.

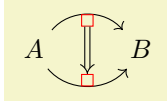


```
\begin{tikzcd}
A \arrow[to=Z, red] \arrow[to=2-2, blue] & B \\
|[alias=Z]| C & D \\
\arrow[from=ul, to=1-2, purple] & 
\end{tikzcd}
```

In the next examples, empty labels are used to create nodes for later reference. The `draw=red` option is used to show where these empty nodes are located, but of course you want to remove that when using this technique.



```
\begin{tikzcd}[column sep=scriptsize]
A \arrow[dr] \arrow[rr, "{name=U, below, draw=red}"] {} & B \\
& & C \arrow[Rightarrow, from=U, "\psi"]
\end{tikzcd}
```

```
\begin{tikzcd}
A \arrow[r, bend left=50, "{name=U, below, draw=red}]
\arrow[r, bend right=50, "{name=D, draw=red}]
& B
\arrow[Rightarrow, from=U, to=D]
\end{tikzcd}
```

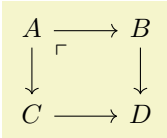
2.4 Phantom arrows

Sometimes it is necessary to insert a symbol outside the grid subjacent to the diagram. The easiest way to achieve this is as a label to an invisible arrow.

`/tikz/commutative diagrams/phantom` (style, no value)

Creates an invisible arrow. Labels to this arrow are not invisible. They will be anchored at their center and typeset in full size (i.e., with `\textstyle`). To get smaller labels, as in ordinary arrows, use the `\scriptstyle` command.

In the picture below, the arrow containing the `phantom` option goes from *A* to *D*, and the `\ulcorner` symbol (\ulcorner) is inserted closer to the starting point *A*.



```
\begin{tikzcd}
A \arrow[r] \arrow[d] \arrow[dr, phantom, "\ulcorner", very near start]
& B \arrow[d] \\
C \arrow[r]
& D
\end{tikzcd}
```

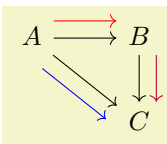
2.5 Fine-tuning the placement of arrows

`/tikz/commutative diagrams/shift left=<dimension>` (default 0.56ex)

Shifts arrows by `<dimension>` to the left, relative to the arrow direction. A dimensionless argument causes that multiple of the default value to be used.

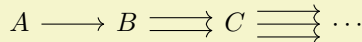
`/tikz/commutative diagrams/shift right=<dimension>` (default 1)

A shortcut to `shift left=-<dimension>`.



```
\begin{tikzcd}
A \arrow[r, red, shift left=1.5ex] \arrow[r]
\arrow[dr, blue, shift right=1.5ex] \arrow[dr]
& B \arrow[d, purple, shift left=1.5ex] \arrow[d] \\
& C
\end{tikzcd}
```

The default values of `shift left` and `shift right` are appropriate for a pair of parallel arrows, and dimensionless arguments are useful to create sets of multiple parallel arrows.



```
\begin{tikzcd}
A \arrow[r]
& B \arrow[r, shift left]
\arrow[r, shift right]
& C \arrow[r]
\arrow[r, shift left=2]
\arrow[r, shift right=2]
& \cdots
\end{tikzcd}
```

`/tikz/commutative diagrams/shift={<coordinate>}` (no default)

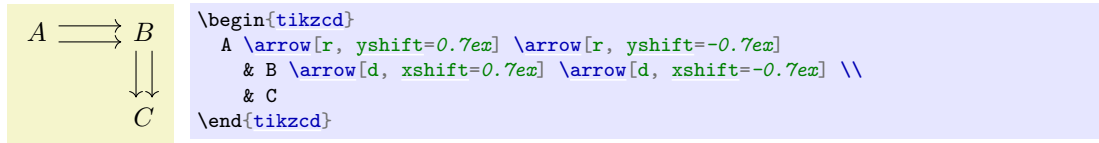
Shifts arrows by `<coordinate>`.

`/tikz/commutative diagrams/xshift=<dimension>` (no default)

Shifts arrows right by `<dimension>`.

`/tikz/commutative diagrams/yshift=<dimension>` (no default)

Shifts arrows up by $\langle dimension \rangle$.



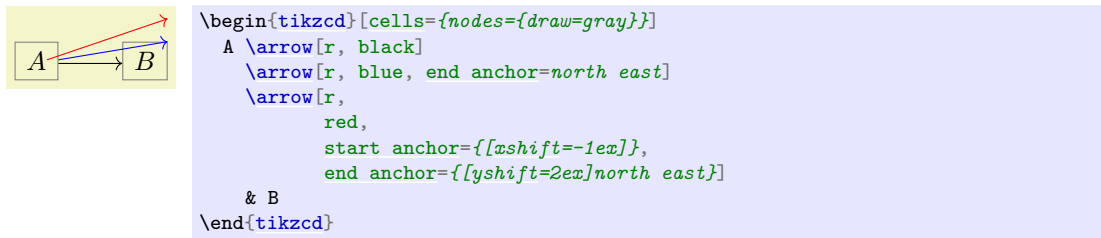
`/tikz/commutative diagrams/start anchor={[[<coordinate transformations>]]<anchor>}` (no default)

This key specifies at which anchor of the source node the arrow should start. Optionally, additional coordinate transformations can be supplied. An empty $\langle anchor \rangle$ argument causes no anchor to be specified, which is the usual behavior.

`/tikz/commutative diagrams/end anchor={[[<coordinate transformations>]]<anchor>}` (no default)

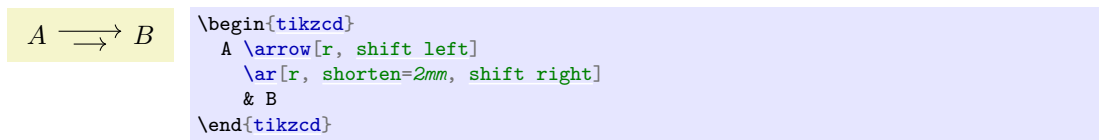
This key works analogously, but refers to the target node of the arrow.

See the picture on §4.1 for some of the possible values for $\langle anchor \rangle$.



`/tikz/commutative diagrams/shorten=<dimension>` (no default)

This key shortens each end of the arrow by $\langle dimension \rangle$.

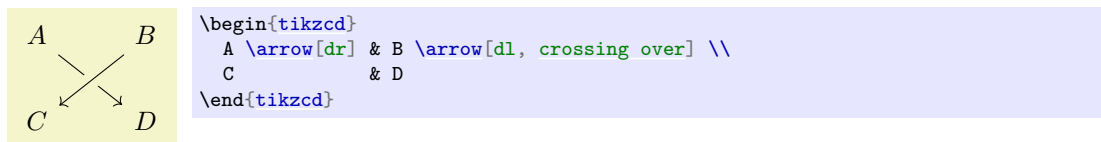


Note that the ends of an arrow can be shortened individually using TikZ's built-in keys `shorten <` and `shorten >`.

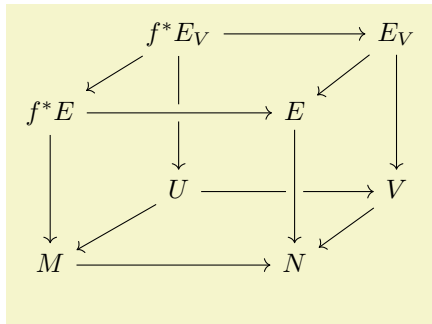
2.6 Three-dimensional diagrams

`/tikz/commutative diagrams/crossing over` (style, no value)

This style makes a thicker line, with color `background_color`, to be drawn under the current arrow, simulating the effect of its passing over other arrows.



Note that, since arrows are drawn in the order they are read, it may be necessary to defer the drawing of certain arrows to achieve the desired result. This can be done using the `from` key, as shown in the following picture.



```
\begin{tikzcd}[row sep=scriptsize, column sep=scriptsize]
& f^*E_V & \longrightarrow & E_V & \\
f^*E & \longrightarrow & E & & \\
& \downarrow & & \downarrow & \\
& U & \longrightarrow & V & \\
M & \longrightarrow & N & & \\
& \swarrow & & \swarrow & \\
& & & & \end{tikzcd}
```

`/tikz/commutative diagrams/crossing over clearance= $\langle dimension \rangle$` (no default, initially 1.5ex)
This key specifies the width of the background-colored line drawn under a `crossing over` arrow.

2.7 Options for labels

`/tikz/commutative diagrams/every label` (style, no value)
This style is applied to every label produced with `\arrow`. It is initially set to

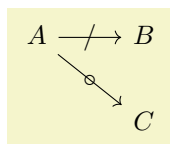
```
/tikz/auto,
/tikz/font= $\langle something \rangle$ ,
/tikz/inner sep=0.5ex
```

where $\langle something \rangle$ is something that makes `\scriptstyle` be applied to labels in math mode.

The key `/tikz/auto` makes the label be placed on the left side of the arrow, relative to its direction. The key `/tikz/inner sep` controls the distance between a label and the corresponding arrow.

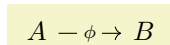
`/tikz/commutative diagrams/labels= $\langle options \rangle$` (no default)
This key appends $\langle options \rangle$ to `every label`.

`/tikz/commutative diagrams/marking` (style, no value)
This style causes the label to be placed over the arrow. It is useful to decorate arrows using ordinary math symbols.



```
\begin{tikzcd}
A & \xrightarrow{/} & B \\
& \searrow @{\circ} & C
\end{tikzcd}
```

`/tikz/commutative diagrams/description` (style, no value)
This style causes the label to be placed over the arrow, with the background filled. The clearance around the label is determined by `/tikz/inner sep`.



```
\begin{tikzcd}
A & \xrightarrow{\phi} & B
\end{tikzcd}
```

3 Advanced usage

This section provides further details on the functioning of this package, with the aim of allowing the advanced user to make a more or less arbitrary use of other TikZ features within `{tikzcd}`.

3.1 Internals of `tikzcd` and the arrow commands

The `{tikzcd}` environment works by substituting code of the form

```
\begin{tikzcd}[\langle options \rangle]
  \langle contents \rangle
\end{tikzcd}
```

with roughly the following:

```
\begin{tikzpicture}[\langle options \rangle]
  \matrix[matrix of nodes] {
    \langle contents \rangle \\
  };
  \langle paths \rangle
\end{tikzpicture}
```

Not shown above are a number of initialization procedures, such as defining `\arrow` and its relatives, as well as applying the default settings specified by `every diagram` and its relatives. Note that the next-row command `\\` for the last row is inserted by `{tikzcd}`, and therefore should not be present in `\langle contents \rangle`. Notice also that you can use the key `execute at end picture` in `\langle options \rangle` to have arbitrary TikZ code executed after a diagram is drawn.

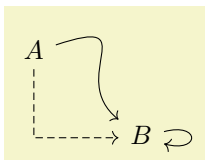
Initially, `\langle paths \rangle` is the empty string. A command `\arrow[\langle options \rangle]` does nothing at the point it is inserted, and causes the following code to be appended to `\langle paths \rangle`:

```
\path[\langle options \rangle] (\langle source node \rangle) to (\langle target node \rangle);
```

By default, `\langle source node \rangle` and `\langle target node \rangle` refer to the node corresponding to the matrix cell where the command `\arrow` is present. This can be changed using the `from` and `to` keys, or a direction argument (a string consisting of characters `r`, `l`, `d`, `u`).

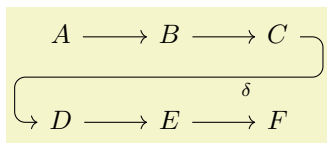
3.2 Tweaking to paths

Recall that the `to path` operation used in the paths created by `\arrow` can take a number of options, as described in §74 of the PGF manual [2]. In particular, the key `/tikz/to path` determines the path that is actually drawn, and can be used to do all sorts of fiddling.



```
\begin{tikzcd}
  A \arrow[dr, controls={+(1.5,0.5) and +(-1,0.8)}]
  \arrow[dr, dashed, to path=/{- (\tikztotarget)}]
  & \\
  & B \arrow[loop right]
\end{tikzcd}
```

The following example shows how to produce a “snake” map. The arrow with the `phantom` option (going from `B` to `E`) has the sole purpose of creating a coordinate, named `Z`, lying halfway between these two cells. The arrow starting at `C` has target `D`, so the macros `\tikztostart` and `\tikztotarget` will expand to the nodes corresponding to these two cells in the argument of `to path`. Notice also the use of `\tikztonodes` at the point where we want the label to be inserted.



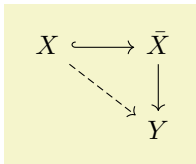
```

\begin{tikzcd}
A \arrow[r]
& B \arrow[r]
& \arrow[d, phantom, "{coordinate, name=Z}"]
& C \arrow[dll,
"\delta",
rounded corners,
to path={ -- ([xshift=2ex]\tikztostart.east)
|- (Z) [near end]\tikztodes
-| ([xshift=-2ex]\tikztotarget.west)
-- (\tikztotarget)}] \
D \arrow[r]
& E \arrow[r]
& F
\end{tikzcd}

```

3.3 Drawing diagrams directly with TikZ

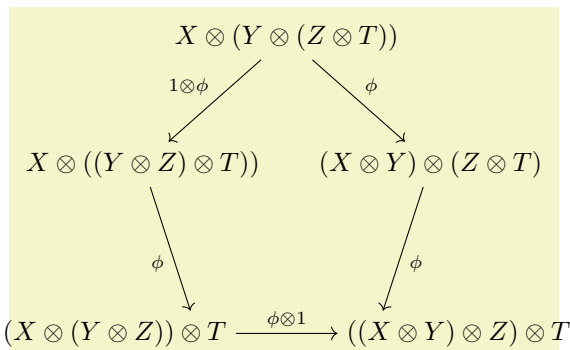
If you find that this package is not flexible enough for some particular application, you can use the methods described in [1] and draw diagrams directly with TikZ. In this case, you can still use the styles provided here to obtain pictures with a uniform appearance throughout your document. The pictures below show how this can be done (the second one is adapted from [1]).



```

\begin{tikzpicture}[commutative diagrams/every diagram]
\matrix[matrix of math nodes, name=m, commutative diagrams/every cell] {
X & \bar{X} \\
& & Y \\
& & & Y
};
\path[commutative diagrams/.cd, every arrow, every label]
(m-1-1) edge[commutative diagrams/hook] (m-1-2)
edge[commutative diagrams/dashed] (m-2-2)
(m-1-2) edge (m-2-2);
\end{tikzpicture}

```



```

\begin{tikzpicture}[commutative diagrams/every diagram]
\node (P0) at (90:2.3cm) {$X \otimes (Y \otimes (Z \otimes T))$};
\node (P1) at (90+72:2cm) {$X \otimes ((Y \otimes Z) \otimes T)$};
\node (P2) at (90+2*72:2cm) {\makebox[5ex][r]{$(X \otimes (Y \otimes Z)) \otimes T$}};
\node (P3) at (90+3*72:2cm) {\makebox[5ex][l]{$((X \otimes Y) \otimes Z) \otimes T$}};
\node (P4) at (90+4*72:2cm) {$X \otimes Y \otimes (Z \otimes T)$};

\path[commutative diagrams/.cd, every arrow, every label]
(P0) edge node[swap] {$1 \otimes \phi$} (P1)
(P1) edge node[swap] {$\phi$} (P2)
(P2) edge node {$\phi \otimes 1$} (P3)
(P4) edge node {$\phi$} (P3)
(P0) edge node {$\phi$} (P4);
\end{tikzpicture}

```

3.4 Issues with active characters

By default, TikZ makes the character & active inside matrices, and this causes the error message

! Package pgfbasematrix Error: Single ampersand used with wrong catcode.

when `{tikzcd}` is used inside the argument to a macro such as a Beamer frame or a footnote. One solution to this problem is to call `{tikzcd}` with the option `ampersand replacement=\&`, and replace all occurrences of `&` with `\&` in the diagram. This procedure is also needed if you want to use matrices in a diagram cell or label.

$A \oplus B \xrightarrow{\begin{pmatrix} e & f \\ g & h \end{pmatrix}} C \oplus D$	<pre>\begin{tikzcd}[ampersand replacement=\&] A \oplus B \ar[r, "{\begin{pmatrix} e & f \\ g & h \end{pmatrix}}"] \& C \oplus D \end{tikzcd}</pre>
------------------------------------------------------------------------------------	--------------------------------------------------------------------------------------------------------------------------------------------------------------------

An alternative fix to this issue that does not require replacing `&` with a different column separator consists in adding the following line to your document after all packages have been loaded:

```
\def\temp{&} \catcode\&=\active \let&=\temp
```

However, this may interfere in unexpected ways with other packages. Use this trick at your own risk.

A different but related issue is that some packages, notably `babel`, modify the catcodes of certain characters in a way that may upset `TikZ`'s parser. To fix this, add

```
\usetikzlibrary{babel}
```

to your document preamble.

4 Additional goodies

This package provides some general PGF infrastructure to achieve its goals. These additional goodies are documented in this section.

4.1 The asymmetrical rectangle shape

The following shape is used inside `{tikzcd}` to ensure that arrows between nodes in the same row are perfectly horizontal, even if the nodes contain text with different heights and depths.

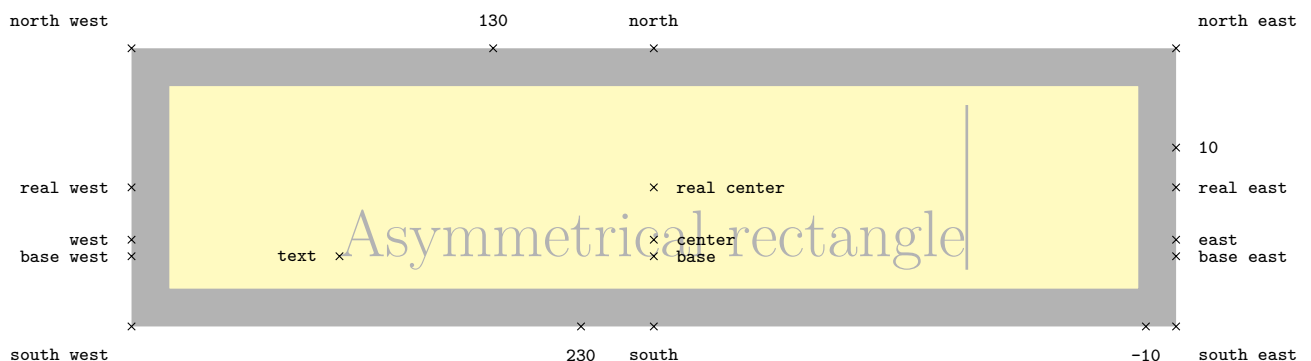
Shape `asymmetrical rectangle`

This shape is similar to the `rectangle` shape, but its `center` is located at a fixed distance of the `base`, as determined by the `center yshift` key, rather than lying at the shape's geometric center. The numerical anchors, as well as `east` and `west`, are modified accordingly, and there are anchors called `real center`, `real east`, and `real west` matching `rectangle`'s original definitions. All other anchors provided by `rectangle` are available and remain unmodified.

`/tikz/commutative diagrams/center yshift=<dimension>` (no default, initially `axis_height`)

Determines the distance between `asymmetrical rectangle`'s `base` and `center` anchors.

The picture below shows some of the available anchors.



4.2 Reading font parameters

The following are `pgfmath` functions used to access relevant math font parameters. They take no arguments, but the result depends of the currently selected font size.

`axis_height`

Returns the axis height parameter (a.k.a. σ_{22}) of the document's math font.

`rule_thickness`

Returns the fraction rule thickness (a.k.a. ξ_8) of the document's math font.

4.3 Computer Modern arrow tips

The following arrow tips mimic the Computer Modern designs. It is useful to know that at size 10pt, the Computer Modern arrow stems are 0.4pt thick; for other font sizes, scale this parameter accordingly, or set `line width=rule_thickness`.

Notice that by using the mechanism explained in §1.3, it is not necessary, and in fact not advisable, to directly refer to the arrow tips listed in this section inside a `{tikzcd}`.

<code>cm to</code>	yields \longleftrightarrow	<code>cm bar</code>	yields $\bar{\longleftrightarrow}$
<code>cm implies</code>	yields \Leftrightarrow	<code>cm left to</code>	yields $\leftarrow\rightarrow$
<code>cm bold to</code>	yields $\boldsymbol{\longleftrightarrow}$	<code>cm right to</code>	yields $\rightarrow\leftarrow$
<code>cm double to</code>	yields \Leftrightarrow	<code>cm left hook</code>	yields $\leftarrow\hookrightarrow$
<code>cm to reversed</code>	yields \rightleftarrows	<code>cm right hook</code>	yields $\rightarrow\hookleftarrow$

4.4 Glyph arrow tips

As an attempt to provide a general solution to the problem of having matching arrow tips in text and pictures, this feature produces arrow tips that consist of (pieces of) font glyphs carefully placed at the endpoints of the path. To activate it in `{tikzcd}` diagrams, refer to the `arrow style` key.

Arrow Tip Kind Glyph

An arrow tip made from a piece of text. It accepts the following parameters.

`/pgf/arrow keys/glyph math command=<name>` (no default)

The name of a command (to be used inside `\csname ...\endcsname`) producing the desired glyph.

`/pgf/arrow keys/glyph length=<dimension>` (no default, initially `1ex`)

The length of the portion of the glyph not clipped away. Also used to set the 'tip end' parameter.

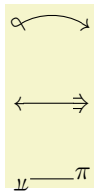
`/pgf/arrow keys/glyph axis=<dimension>` (no default, initially `axis_height`)

A vertical displacement applied to the glyph in order to make the glyph's central axis (typically an arrow stem) aligned with the path.

`/pgf/arrow keys/glyph shorten=<dimension>` (no default, initially `-0.1ex`)

An additional amount by which the end of the path is shortened. This is used to compensate for the gap that usually exists between the tip end and the glyph's bounding box.

Below are some usage examples. Notice that glyph arrow tips do not scale with PGF line width but their size depends on the current font size, so you will probably want to set `line width=rule_thickness` when using them. Also, contrarily to the arrow parameters defined by the `arrows.meta` library, the parameters described above are evaluated only at the time the arrow tip is drawn, so they can (and should) be given in the units `em` or `ex`.



```

\tikzset{
  math to/.tip={Glyph[glyph math command=rightarrow]},
  loop/.tip={Glyph[glyph math command=looparrowleft, swap]},
  weird/.tip={Glyph[glyph math command=Rrightarrow, glyph length=1.5ex]},
  pi/.tip={Glyph[glyph math command=pi, glyph length=1.5ex, glyph axis=0pt]},
}

\begin{tikzpicture}[line width=rule_thickness]
  \draw[loop-math to, bend left] (0,2) to (1,2);
  \draw[math to-weird] (0,1) to (1,1);
  \draw[pi-pi] (0,0) to (1,0);
\end{tikzpicture}

```

It is important to be aware of some drawbacks of this feature. First, the transition between a line and the arrow tip may become visible with some printers (especially in low resolutions or draft mode) and document viewers, as you may be able to see in the samples above. Second, these rather long tips may ($--\rightarrow$) or may not ($--\rightarrow$) fit nicely with dashed or curved lines. Finally, the method used to place the arrow tip at the end of a stroked path and clip away the arrow stem makes certain assumptions about the font design and could fail in cases where unusual design choices are made.

References

- [1] James Milne, *Guide to commutative diagrams*. Available at <http://www.jmilne.org/not/CDGuide.html>.
- [2] Till Tantau, *The TikZ and PGF packages: Manual for version 3.1.9*. Available at <http://mirrors.ctan.org/graphics/pgf/base/doc/pgfmanual.pdf>.

Index

This index only contains automatically generated entries. A good index should also contain carefully selected keywords. This index is not a good index.

- \ar, 2
- \arrow, 2, 4
- arrow style key, 8
- Arrow tips
 - cm bar, 15
 - cm bold to, 15
 - cm double to, 15
 - cm implies, 15
 - cm left hook, 15
 - cm left to, 15
 - cm right hook, 15
 - cm right to, 15
 - cm to, 15
 - cm to reversed, 15
 - Glyph, 15
- arrows key, 7
- asymmetrical rectangle shape, 14
- axis_height math function, 15

- background color key, 7

- cd library, 1, 5
- cells key, 6
- center yshift key, 14
- cm bar arrow tip, 15
- cm bold to arrow tip, 15
- cm double to arrow tip, 15
- cm implies arrow tip, 15
- cm left hook arrow tip, 15
- cm left to arrow tip, 15
- cm right hook arrow tip, 15
- cm right to arrow tip, 15
- cm to arrow tip, 15
- cm to reversed arrow tip, 15
- column sep key, 6
- cramped key, 7
- crossing over key, 10
- crossing over clearance key, 11

- \dar, 4
- dash key, 4
- dashed key, 4
- dashleftarrow key, 4
- dashrightarrow key, 4
- description key, 11
- diagrams key, 6
- \dlar, 5
- \drar, 4

- end anchor key, 10
- Environments
 - tikzcd, 2, 5
- equal key, 4
- every arrow key, 7
- every cell key, 6
- every diagram key, 6
- every label key, 11

- every matrix key, 6

- from key, 8

- Glyph arrow tip, 15
- glyph axis key, 15
- glyph length key, 15
- glyph math command key, 15
- glyph shorten key, 15

- harpoon key, 4
- harpoon' key, 4
- hook key, 4
- hook' key, 4
- hookleftarrow key, 4
- hookrightarrow key, 4

- labels key, 11
- \lar, 4
- Leftarrow key, 3
- leftarrow key, 3
- leftarrowtail key, 4
- leftharpoondown key, 4
- leftharpoonup key, 4
- Leftrightarrow key, 3
- leftrightarrow key, 3
- leftrightsquigarrow key, 4
- leftsquigarrow key, 4
- Libraries
 - cd, 1, 5

- maps to key, 3
- Mapsfrom key, 3
- mapsfrom key, 3
- Mapsto key, 3
- mapsto key, 3
- marking key, 11
- Math functions
 - axis_height, 15
 - rule_thickness, 15
- math mode key, 7

- no head key, 4
- no tail key, 4

- Packages and files
 - tikz-cd, 1
- /pgf/
 - arrow keys/
 - glyph axis, 15
 - glyph length, 15
 - glyph math command, 15
 - glyph shorten, 15
 - phantom key, 9

- \rar, 4
- Rightarrow key, 3
- rightarrow key, 3

- rightarrowtail key, 4
- rightharpoondown key, 4
- rightharpoonup key, 4
- rightsquigarrow key, 4
- row sep key, 6
- rule_thickness math function, 15

- sep key, 7
- Shapes
 - asymmetrical rectangle, 14
- shift key, 9
- shift left key, 9
- shift right key, 9
- shorten key, 10
- squiggly key, 4
- start anchor key, 10

- tail key, 4
- /tikz/
 - commutative diagrams/
 - arrow style, 8
 - arrows, 7
 - background color, 7
 - cells, 6
 - center yshift, 14
 - column sep, 6
 - cramped, 7
 - crossing over, 10
 - crossing over clearance, 11
 - dash, 4
 - dashed, 4
 - dashleftarrow, 4
 - dashrightarrow, 4
 - description, 11
 - diagrams, 6
 - end anchor, 10
 - equal, 4
 - every arrow, 7
 - every cell, 6
 - every diagram, 6
 - every label, 11
 - every matrix, 6
 - from, 8
 - harpoon, 4
 - harpoon', 4
 - hook, 4
 - hook', 4
 - hookleftarrow, 4
 - hookrightarrow, 4
 - labels, 11
 - Leftarrow, 3
 - leftarrow, 3
 - leftarrowtail, 4
 - leftharpoondown, 4
 - leftharpoonup, 4
 - Leftrightarrow, 3
 - leftrightharpoonup, 3
 - leftrightsquigarrow, 4
 - leftsquigarrow, 4
 - maps to, 3
 - Mapsfrom, 3
 - mapsfrom, 3
 - Mapsto, 3
 - mapsto, 3
 - marking, 11
 - math mode, 7
 - no head, 4
 - no tail, 4
 - phantom, 9
 - Rightarrow, 3
 - rightarrow, 3
 - rightarrowtail, 4
 - rightharpoondown, 4
 - rightharpoonup, 4
 - rightsquigarrow, 4
 - row sep, 6
 - sep, 7
 - shift, 9
 - shift left, 9
 - shift right, 9
 - shorten, 10
 - squiggly, 4
 - start anchor, 10
 - tail, 4
 - to, 8
 - to head, 3
 - two heads, 4
 - twoheadleftarrow, 4
 - twoheadrightarrow, 4
 - xshift, 9
 - yshift, 10
- tikz-cd package, 1
- tikzcd environment, 2, 5
- \tikzcdset, 5
- to key, 8
- to head key, 3
- two heads key, 4
- twoheadleftarrow key, 4
- twoheadrightarrow key, 4

- \uar, 4
- \ular, 5
- \urar, 5

- xshift key, 9

- yshift key, 10