

Reformulations of the Axiom of Choice

The axiom

Axiom of Choice (AC).

Axiom of Choice (AC). Given a set A of nonempty, pairwise-disjoint sets, there is a set C that intersects each element of A in exactly one element.

Axiom of Choice (AC). Given a set A of nonempty, pairwise-disjoint sets, there is a set C that intersects each element of A in exactly one element.

Since introducing this axiom, we have introduced the notion of a *partition*.

Axiom of Choice (AC). Given a set A of nonempty, pairwise-disjoint sets, there is a set C that intersects each element of A in exactly one element.

Since introducing this axiom, we have introduced the notion of a *partition*. A partition of a set X is a set $\Pi = \{X_i \subseteq X \mid i \in I\}$ of nonempty, pairwise-disjoint subsets of X whose union is X .

Axiom of Choice (AC). Given a set A of nonempty, pairwise-disjoint sets, there is a set C that intersects each element of A in exactly one element.

Since introducing this axiom, we have introduced the notion of a *partition*. A partition of a set X is a set $\Pi = \{X_i \subseteq X \mid i \in I\}$ of nonempty, pairwise-disjoint subsets of X whose union is X . Using this language, we may reformulate AC as:

Axiom of Choice (AC). Given a set A of nonempty, pairwise-disjoint sets, there is a set C that intersects each element of A in exactly one element.

Since introducing this axiom, we have introduced the notion of a *partition*. A partition of a set X is a set $\Pi = \{X_i \subseteq X \mid i \in I\}$ of nonempty, pairwise-disjoint subsets of X whose union is X . Using this language, we may reformulate AC as:

Every partition has a transversal.

Axiom of Choice (AC). Given a set A of nonempty, pairwise-disjoint sets, there is a set C that intersects each element of A in exactly one element.

Since introducing this axiom, we have introduced the notion of a *partition*. A partition of a set X is a set $\Pi = \{X_i \subseteq X \mid i \in I\}$ of nonempty, pairwise-disjoint subsets of X whose union is X . Using this language, we may reformulate AC as:

Every partition has a transversal.

A “transversal” for a partition Π of X means either

Axiom of Choice (AC). Given a set A of nonempty, pairwise-disjoint sets, there is a set C that intersects each element of A in exactly one element.

Since introducing this axiom, we have introduced the notion of a *partition*. A partition of a set X is a set $\Pi = \{X_i \subseteq X \mid i \in I\}$ of nonempty, pairwise-disjoint subsets of X whose union is X . Using this language, we may reformulate AC as:

Every partition has a transversal.

A “transversal” for a partition Π of X means either

- 1 a set $T \subseteq X$ such that T contains exactly one element from each cell of Π ,

Axiom of Choice (AC). Given a set A of nonempty, pairwise-disjoint sets, there is a set C that intersects each element of A in exactly one element.

Since introducing this axiom, we have introduced the notion of a *partition*. A partition of a set X is a set $\Pi = \{X_i \subseteq X \mid i \in I\}$ of nonempty, pairwise-disjoint subsets of X whose union is X . Using this language, we may reformulate AC as:

Every partition has a transversal.

A “transversal” for a partition Π of X means either

- 1 a set $T \subseteq X$ such that T contains exactly one element from each cell of Π ,

Axiom of Choice (AC). Given a set A of nonempty, pairwise-disjoint sets, there is a set C that intersects each element of A in exactly one element.

Since introducing this axiom, we have introduced the notion of a *partition*. A partition of a set X is a set $\Pi = \{X_i \subseteq X \mid i \in I\}$ of nonempty, pairwise-disjoint subsets of X whose union is X . Using this language, we may reformulate AC as:

Every partition has a transversal.

A “transversal” for a partition Π of X means either

- 1 a set $T \subseteq X$ such that T contains exactly one element from each cell of Π , or

Axiom of Choice (AC). Given a set A of nonempty, pairwise-disjoint sets, there is a set C that intersects each element of A in exactly one element.

Since introducing this axiom, we have introduced the notion of a *partition*. A partition of a set X is a set $\Pi = \{X_i \subseteq X \mid i \in I\}$ of nonempty, pairwise-disjoint subsets of X whose union is X . Using this language, we may reformulate AC as:

Every partition has a transversal.

A “transversal” for a partition Π of X means either

- 1 a set $T \subseteq X$ such that T contains exactly one element from each cell of Π , or
- 2 a function $t: \Pi \rightarrow X$ such that $\text{im}(t)$ contains exactly one element from each cell of Π .

Axiom of Choice (AC). Given a set A of nonempty, pairwise-disjoint sets, there is a set C that intersects each element of A in exactly one element.

Since introducing this axiom, we have introduced the notion of a *partition*. A partition of a set X is a set $\Pi = \{X_i \subseteq X \mid i \in I\}$ of nonempty, pairwise-disjoint subsets of X whose union is X . Using this language, we may reformulate AC as:

Every partition has a transversal.

A “transversal” for a partition Π of X means either

- 1 a set $T \subseteq X$ such that T contains exactly one element from each cell of Π , or
- 2 a function $t: \Pi \rightarrow X$ such that $\text{im}(t)$ contains exactly one element from each cell of Π .

Axiom of Choice (AC). Given a set A of nonempty, pairwise-disjoint sets, there is a set C that intersects each element of A in exactly one element.

Since introducing this axiom, we have introduced the notion of a *partition*. A partition of a set X is a set $\Pi = \{X_i \subseteq X \mid i \in I\}$ of nonempty, pairwise-disjoint subsets of X whose union is X . Using this language, we may reformulate AC as:

Every partition has a transversal.

A “transversal” for a partition Π of X means either

- 1 a set $T \subseteq X$ such that T contains exactly one element from each cell of Π , or
- 2 a function $t: \Pi \rightarrow X$ such that $\text{im}(t)$ contains exactly one element from each cell of Π .

That is,

Axiom of Choice (AC). Given a set A of nonempty, pairwise-disjoint sets, there is a set C that intersects each element of A in exactly one element.

Since introducing this axiom, we have introduced the notion of a *partition*. A partition of a set X is a set $\Pi = \{X_i \subseteq X \mid i \in I\}$ of nonempty, pairwise-disjoint subsets of X whose union is X . Using this language, we may reformulate AC as:

Every partition has a transversal.

A “transversal” for a partition Π of X means either

- 1 a set $T \subseteq X$ such that T contains exactly one element from each cell of Π , or
- 2 a function $t: \Pi \rightarrow X$ such that $\text{im}(t)$ contains exactly one element from each cell of Π .

That is, a “transversal” for Π is either a “choice set” for Π

Axiom of Choice (AC). Given a set A of nonempty, pairwise-disjoint sets, there is a set C that intersects each element of A in exactly one element.

Since introducing this axiom, we have introduced the notion of a *partition*. A partition of a set X is a set $\Pi = \{X_i \subseteq X \mid i \in I\}$ of nonempty, pairwise-disjoint subsets of X whose union is X . Using this language, we may reformulate AC as:

Every partition has a transversal.

A “transversal” for a partition Π of X means either

- 1 a set $T \subseteq X$ such that T contains exactly one element from each cell of Π , or
- 2 a function $t: \Pi \rightarrow X$ such that $\text{im}(t)$ contains exactly one element from each cell of Π .

That is, a “transversal” for Π is either a “choice set” for Π or a “choice function” for Π .

A “section” of a surjective function

A “section” of a surjective function

A *section* of a surjective function $f: X \rightarrow Y$ is a right inverse of the function:

A “section” of a surjective function

A *section* of a surjective function $f: X \rightarrow Y$ is a right inverse of the function: $s: Y \rightarrow X$ such that $f \circ s = \text{id}_Y$.

A “section” of a surjective function

A *section* of a surjective function $f: X \rightarrow Y$ is a right inverse of the function: $s: Y \rightarrow X$ such that $f \circ s = \text{id}_Y$. The natural map for a partition,

A “section” of a surjective function

A *section* of a surjective function $f: X \rightarrow Y$ is a right inverse of the function: $s: Y \rightarrow X$ such that $f \circ s = \text{id}_Y$. The natural map for a partition,

$$\nu_\Pi: X \rightarrow \Pi: x \mapsto [x]_\Pi$$

is surjective.

A “section” of a surjective function

A *section* of a surjective function $f: X \rightarrow Y$ is a right inverse of the function: $s: Y \rightarrow X$ such that $f \circ s = \text{id}_Y$. The natural map for a partition,

$$\nu_\Pi: X \rightarrow \Pi: x \mapsto [x]_\Pi$$

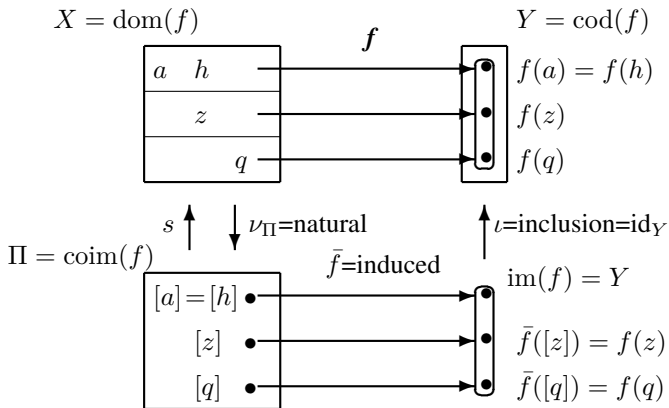
is surjective. A “section of ν_Π ” means the same thing as “a transversal for Π ”.

A “section” of a surjective function

A *section* of a surjective function $f: X \rightarrow Y$ is a right inverse of the function: $s: Y \rightarrow X$ such that $f \circ s = \text{id}_Y$. The natural map for a partition,

$$\nu_\Pi: X \rightarrow \Pi: x \mapsto [x]_\Pi$$

is surjective. A “section of ν_Π ” means the same thing as “a transversal for Π ”.



First reformulations of AC

First reformulations of AC

ZFC

First reformulations of AC

$$\text{ZFC} = \text{ZF} + \text{AC}$$

First reformulations of AC

ZFC = ZF + AC \equiv ZF + (any of these):

First reformulations of AC

ZFC = ZF + AC \equiv ZF + (any of these):

- 1 Every partition has a transversal

First reformulations of AC

ZFC = ZF + AC \equiv ZF + (any of these):

- 1 Every partition has a transversal

First reformulations of AC

ZFC = ZF + AC \equiv ZF + (any of these):

- ① Every partition has a transversal (= choice set).

First reformulations of AC

ZFC = ZF + AC \equiv ZF + (any of these):

- ① Every partition has a transversal (= choice set).
- ② Every partition has a transversal

First reformulations of AC

ZFC = ZF + AC \equiv ZF + (any of these):

- 1 Every partition has a transversal (= choice set).
- 2 Every partition has a transversal

First reformulations of AC

ZFC = ZF + AC \equiv ZF + (any of these):

- 1 Every partition has a transversal (= choice set).
- 2 Every partition has a transversal (= choice function).

First reformulations of AC

ZFC = ZF + AC \equiv ZF + (any of these):

- 1 Every partition has a transversal (= choice set).
- 2 Every partition has a transversal (= choice function).
- 3 Every surjective function has a section.

Choice for set systems that are not partitions (page 139, HJ)

Assume that A is a set of nonempty sets.

Choice for set systems that are not partitions (page 139, HJ)

Assume that A is a set of nonempty sets. We can create a corresponding set \hat{A} of pairwise disjoint nonempty sets

Choice for set systems that are not partitions (page 139, HJ)

Assume that A is a set of nonempty sets. We can create a corresponding set \hat{A} of pairwise disjoint nonempty sets (a partition),

Assume that A is a set of nonempty sets. We can create a corresponding set \hat{A} of pairwise disjoint nonempty sets (a partition), let \hat{c} be a choice function for \hat{A} ,

Assume that A is a set of nonempty sets. We can create a corresponding set \hat{A} of pairwise disjoint nonempty sets (a partition), let \hat{c} be a choice function for \hat{A} , then use \hat{c} to create a choice function c for A . Thus, using choice functions instead of choice sets,

Assume that A is a set of nonempty sets. We can create a corresponding set \hat{A} of pairwise disjoint nonempty sets (a partition), let \hat{c} be a choice function for \hat{A} , then use \hat{c} to create a choice function c for A . Thus, using choice functions instead of choice sets, we can generalize our uses of choice from partitions to arbitrary sets of nonempty sets.

Assume that A is a set of nonempty sets. We can create a corresponding set \hat{A} of pairwise disjoint nonempty sets (a partition), let \hat{c} be a choice function for \hat{A} , then use \hat{c} to create a choice function c for A . Thus, using choice functions instead of choice sets, we can generalize our uses of choice from partitions to arbitrary sets of nonempty sets.

Example.

Assume that A is a set of nonempty sets. We can create a corresponding set \widehat{A} of pairwise disjoint nonempty sets (a partition), let \widehat{c} be a choice function for \widehat{A} , then use \widehat{c} to create a choice function c for A . Thus, using choice functions instead of choice sets, we can generalize our uses of choice from partitions to arbitrary sets of nonempty sets.

Example. Let $A = \{X, Y, Z\} = \{\{x_0, x_1\}, \{y_0\}, \{z_0, z_1, z_2\}\}$.

Assume that A is a set of nonempty sets. We can create a corresponding set \widehat{A} of pairwise disjoint nonempty sets (a partition), let \widehat{c} be a choice function for \widehat{A} , then use \widehat{c} to create a choice function c for A . Thus, using choice functions instead of choice sets, we can generalize our uses of choice from partitions to arbitrary sets of nonempty sets.

Example. Let $A = \{X, Y, Z\} = \{\{x_0, x_1\}, \{y_0\}, \{z_0, z_1, z_2\}\}$.

$$\widehat{A} = \{X \times \{X\}, Y \times \{Y\}, Z \times \{Z\}\}$$

Assume that A is a set of nonempty sets. We can create a corresponding set \widehat{A} of pairwise disjoint nonempty sets (a partition), let \widehat{c} be a choice function for \widehat{A} , then use \widehat{c} to create a choice function c for A . Thus, using choice functions instead of choice sets, we can generalize our uses of choice from partitions to arbitrary sets of nonempty sets.

Example. Let $A = \{X, Y, Z\} = \{\{x_0, x_1\}, \{y_0\}, \{z_0, z_1, z_2\}\}$.

$\widehat{A} = \{X \times \{X\}, Y \times \{Y\}, Z \times \{Z\}\}$ = a partition.

Assume that A is a set of nonempty sets. We can create a corresponding set \widehat{A} of pairwise disjoint nonempty sets (a partition), let \widehat{c} be a choice function for \widehat{A} , then use \widehat{c} to create a choice function c for A . Thus, using choice functions instead of choice sets, we can generalize our uses of choice from partitions to arbitrary sets of nonempty sets.

Example. Let $A = \{X, Y, Z\} = \{\{x_0, x_1\}, \{y_0\}, \{z_0, z_1, z_2\}\}$.

$\widehat{A} = \{X \times \{X\}, Y \times \{Y\}, Z \times \{Z\}\}$ = a partition.

Questions.

Assume that A is a set of nonempty sets. We can create a corresponding set \widehat{A} of pairwise disjoint nonempty sets (a partition), let \widehat{c} be a choice function for \widehat{A} , then use \widehat{c} to create a choice function c for A . Thus, using choice functions instead of choice sets, we can generalize our uses of choice from partitions to arbitrary sets of nonempty sets.

Example. Let $A = \{X, Y, Z\} = \{\{x_0, x_1\}, \{y_0\}, \{z_0, z_1, z_2\}\}$.

$\widehat{A} = \{X \times \{X\}, Y \times \{Y\}, Z \times \{Z\}\}$ = a partition.

Questions.

- 1 How do we construct \widehat{A} from A , in general?

Assume that A is a set of nonempty sets. We can create a corresponding set \widehat{A} of pairwise disjoint nonempty sets (a partition), let \widehat{c} be a choice function for \widehat{A} , then use \widehat{c} to create a choice function c for A . Thus, using choice functions instead of choice sets, we can generalize our uses of choice from partitions to arbitrary sets of nonempty sets.

Example. Let $A = \{X, Y, Z\} = \{\{x_0, x_1\}, \{y_0\}, \{z_0, z_1, z_2\}\}$.

$\widehat{A} = \{X \times \{X\}, Y \times \{Y\}, Z \times \{Z\}\}$ = a partition.

Questions.

- 1 How do we construct \widehat{A} from A , in general?

Assume that A is a set of nonempty sets. We can create a corresponding set \widehat{A} of pairwise disjoint nonempty sets (a partition), let \widehat{c} be a choice function for \widehat{A} , then use \widehat{c} to create a choice function c for A . Thus, using choice functions instead of choice sets, we can generalize our uses of choice from partitions to arbitrary sets of nonempty sets.

Example. Let $A = \{X, Y, Z\} = \{\{x_0, x_1\}, \{y_0\}, \{z_0, z_1, z_2\}\}$.

$\widehat{A} = \{X \times \{X\}, Y \times \{Y\}, Z \times \{Z\}\}$ = a partition.

Questions.

- 1 How do we construct \widehat{A} from A , in general?

$$F: A \rightarrow \mathcal{P}((\cup A) \times A)$$

Assume that A is a set of nonempty sets. We can create a corresponding set \widehat{A} of pairwise disjoint nonempty sets (a partition), let \widehat{c} be a choice function for \widehat{A} , then use \widehat{c} to create a choice function c for A . Thus, using choice functions instead of choice sets, we can generalize our uses of choice from partitions to arbitrary sets of nonempty sets.

Example. Let $A = \{X, Y, Z\} = \{\{x_0, x_1\}, \{y_0\}, \{z_0, z_1, z_2\}\}$.

$\widehat{A} = \{X \times \{X\}, Y \times \{Y\}, Z \times \{Z\}\}$ = a partition.

Questions.

- ① How do we construct \widehat{A} from A , in general?
 $F: A \rightarrow \mathcal{P}((\cup A) \times A): X \mapsto X \times \{X\};$

Assume that A is a set of nonempty sets. We can create a corresponding set \widehat{A} of pairwise disjoint nonempty sets (a partition), let \widehat{c} be a choice function for \widehat{A} , then use \widehat{c} to create a choice function c for A . Thus, using choice functions instead of choice sets, we can generalize our uses of choice from partitions to arbitrary sets of nonempty sets.

Example. Let $A = \{X, Y, Z\} = \{\{x_0, x_1\}, \{y_0\}, \{z_0, z_1, z_2\}\}$.

$\widehat{A} = \{X \times \{X\}, Y \times \{Y\}, Z \times \{Z\}\}$ = a partition.

Questions.

- 1 How do we construct \widehat{A} from A , in general?

$$F: A \rightarrow \mathcal{P}((\cup A) \times A): X \mapsto X \times \{X\}; \quad \widehat{A} := \text{im}(F).$$

Assume that A is a set of nonempty sets. We can create a corresponding set \widehat{A} of pairwise disjoint nonempty sets (a partition), let \widehat{c} be a choice function for \widehat{A} , then use \widehat{c} to create a choice function c for A . Thus, using choice functions instead of choice sets, we can generalize our uses of choice from partitions to arbitrary sets of nonempty sets.

Example. Let $A = \{X, Y, Z\} = \{\{x_0, x_1\}, \{y_0\}, \{z_0, z_1, z_2\}\}$.

$\widehat{A} = \{X \times \{X\}, Y \times \{Y\}, Z \times \{Z\}\}$ = a partition.

Questions.

- ① How do we construct \widehat{A} from A , in general?
 $F: A \rightarrow \mathcal{P}((\cup A) \times A): X \mapsto X \times \{X\}; \quad \widehat{A} := \text{im}(F).$
- ② How do we then construct c from \widehat{c} ?

Assume that A is a set of nonempty sets. We can create a corresponding set \widehat{A} of pairwise disjoint nonempty sets (a partition), let \widehat{c} be a choice function for \widehat{A} , then use \widehat{c} to create a choice function c for A . Thus, using choice functions instead of choice sets, we can generalize our uses of choice from partitions to arbitrary sets of nonempty sets.

Example. Let $A = \{X, Y, Z\} = \{\{x_0, x_1\}, \{y_0\}, \{z_0, z_1, z_2\}\}$.

$\widehat{A} = \{X \times \{X\}, Y \times \{Y\}, Z \times \{Z\}\}$ = a partition.

Questions.

- How do we construct \widehat{A} from A , in general?
 $F: A \rightarrow \mathcal{P}((\cup A) \times A): X \mapsto X \times \{X\}; \quad \widehat{A} := \text{im}(F).$
- How do we then construct c from \widehat{c} ?

Assume that A is a set of nonempty sets. We can create a corresponding set \widehat{A} of pairwise disjoint nonempty sets (a partition), let \widehat{c} be a choice function for \widehat{A} , then use \widehat{c} to create a choice function c for A . Thus, using choice functions instead of choice sets, we can generalize our uses of choice from partitions to arbitrary sets of nonempty sets.

Example. Let $A = \{X, Y, Z\} = \{\{x_0, x_1\}, \{y_0\}, \{z_0, z_1, z_2\}\}$.

$\widehat{A} = \{X \times \{X\}, Y \times \{Y\}, Z \times \{Z\}\}$ = a partition.

Questions.

- ① How do we construct \widehat{A} from A , in general?

$$F: A \rightarrow \mathcal{P}((\cup A) \times A): X \mapsto X \times \{X\}; \quad \widehat{A} := \text{im}(F).$$

- ② How do we then construct c from \widehat{c} ?

$$c = \pi_1 \circ \widehat{c} \circ F.$$

Formally stronger (but equivalent) reformulations of AC

Formally stronger (but equivalent) reformulations of AC

ZFC

Formally stronger (but equivalent) reformulations of AC

$$\text{ZFC} = \text{ZF} + \text{AC}$$

Formally stronger (but equivalent) reformulations of AC

ZFC = ZF + AC \equiv ZF + (any of these):

Formally stronger (but equivalent) reformulations of AC

ZFC = ZF + AC \equiv ZF + (any of these):

- ① Every set of nonempty sets has a choice function.

Formally stronger (but equivalent) reformulations of AC

ZFC = ZF + AC \equiv ZF + (any of these):

- ① Every set of nonempty sets has a choice function.

Formally stronger (but equivalent) reformulations of AC

ZFC = ZF + AC \equiv ZF + (any of these):

- ① Every set of nonempty sets has a choice function.

Formally stronger (but equivalent) reformulations of AC

ZFC = ZF + AC \equiv ZF + (any of these):

- 1 Every set of nonempty sets has a choice function.
- 2 For every set A , the set $\mathcal{P}(A) \setminus \{\emptyset\}$ has a choice function.

Formally stronger (but equivalent) reformulations of AC

ZFC = ZF + AC \equiv ZF + (any of these):

- 1 Every set of nonempty sets has a choice function.
- 2 For every set A , the set $\mathcal{P}(A) \setminus \{\emptyset\}$ has a choice function.

Formally stronger (but equivalent) reformulations of AC

ZFC = ZF + AC \equiv ZF + (any of these):

- 1 Every set of nonempty sets has a choice function.
- 2 For every set A , the set $\mathcal{P}(A) \setminus \{\emptyset\}$ has a choice function. (Such a function is called a “choice function for A ”.)