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The social structure of Risso's Dolphins (*Grampus griseus*) off the south coast of Pico Island, Azores

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Preface

This study was conducted in the context of a master's thesis in Wildlife Ecology and Wildlife Management at the University of Natural Resources and Life Sciences in Vienna, Austria. There are a number of people I would like to thank for their support and help with completing this study.

First of all, I would like to thank my family for all their support throughout all my life and their encouragement to always choose my way, even though it sometimes was a bit rocky. Without their constant backup and also financial assistance especially during my years of studying, I would not have been able to complete this.

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Furthermore, I would like to thank Karin Hartman, of the Nova Atlantis Foundation, who gave me the opportunity to conduct this study and use data of this interesting species at a very beautiful place on earth. I also have to thank my two co-students, Sandra Rybicki and Laura Oller López, without whose help it would have taken me a lot longer to get all the data organized. Next to that I have to thank all the people on Pico Island who made my stay there unforgettable and really special.

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Thank you so much! Oldenburg, Germany, February 2012
Britta Adam

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Zusammenfassung

Die Sozialstrukturen mehrerer wildlebender Wal- und Delfinarten wurde bereits untersucht: z.B. von Pottwalen (*Physeter macrocephalus*), Grindwalen (*Globicephala* spp), Orcas (*Orcinus orca*) und Großen Tümmlern (*Tursiops truncates*). Für Rundkopfdelfine (*Grampus griseus*) allerdings wurde dies bisher kaum erforscht. Ein Grund hierfür sind ihre Vorliebe für Hochseegebiete und ihr hauptsächliches Vorkommen in diesen. Vor der Südküste der Insel Pico, Azoren, widmeten sich 2008 Hartmann *et al*. diesem Thema. Hier herrschen selbst in unmittelbarer Küstennähe optimale Lebensbedingungen für Rundkopfdelfine. Die Art ist durch ihre besondere Farbgebung optimal für Foto-Identifikations-Studien geeignet. Das Ziel der vorliegenden Arbeit war es zu testen, ob die in 2008 festgestellten Ergebnisse noch gültig sind, wenn ein vergrößerter Datensatz und eine geringere Sichtungsrate Einfluss finden. Solch geringere Sichtungsdaten sind ähnlich zu vergleichbaren Untersuchungen an anderen Arten. Zu diesem Zweck wurden die Daten von Hartman *et al*. (2008) überarbeitet und zusammen mit Daten eines zusätzlichen Jahres analysiert. Ob die früheren Ergebnisse noch zutreffen und in wie weit sich diese durch abgeänderte Sichtungsraten verändern, wurde mit Hilfe einer hierarchischen Clusteranalyse in R ermittelt. Zusätzlich wurde mit Hilfe einer einfaktoriellen ANOVA getestet, in wie weit Unterschiede in der Anwesenheit zwischen verschiedenen Monaten, Jahreszeiten und Jahren festzustellen sind.

Es konnte festgestellt werden, dass Analysen mit einem größeren Datensatz die Resultate von 2008 bestätigen. Rundkopfdelfine haben eine komplexe, entlang von Geschlechts- und Altersklassen geschichtete, Sozialstruktur. Es werden entweder langfristig stabile Gruppen, Zweiergruppen, oder gar keine Verbände geformt, je nach dem zu welcher Geschlechts- und Altersgruppe die jeweiligen Tiere gehören. Die stabilsten Verbände sind bei erwachsenen Männchen zu finden, die lockersten bei Subadulten beider Geschlechter. Die Gründe Gruppen zu formen sind unterschiedlich zwischen den Geschlechtern. Bei den Weibchen scheint vor allem die soziale Unterstützung innerhalb der Gruppe bei der Aufzucht der Kälber die größte Rolle zu spielen, wohingegen der ausschlaggebendste Faktor bei Männchen Zugang zu fruchtbaren Weibchen ist. Die geringere Sichtungsrate veränderte die Resultate geringfügig. Im Allgemeinen wurden mehr Gruppen geformt als bei der höheren Sichtungsrate und die Sozialstruktur erschien dynamischer, eher in Richtung ‚fission-fusion' Gesellschaft anstatt das in 2008 gefundene geschichtete Model. Dieses Ergebnis unterstützt die Idee, dass der Rundkopfdelfin-Gesellschaft tatsächlich ein ‚fission-fusion' Model zugrunde liegt, was jedoch in Richtung komplexe Schichtung geht, aufgrund der verschiedenen Ansprüche der unterschiedlichen Geschlechts- und Altersklassen. In Hinsicht auf Unterschiede in der Anwesenheit konnten sowohl zwischen Monaten als auch Jahreszeiten und Jahren signifikante Unterschiede gefunden werden. Diese lagen primär zwischen Frühjahr/Sommer und Herbst/Winter mit höherer Anwesenheit in letzterem und zwischen den ersten beiden Studienjahren und den letzten beiden. Die vor allem im Frühjahr und Sommer stattfindenden Whale Watching Aktivitäten im Untersuchungsgebiet

scheinen einen großen Einfluss auf diese Verteilung zu haben. Was noch zu untersuchen bleibt sind eventuelle Auswirkungen von weiteren Umweltfaktoren. Anwesenheit von Beute, Veränderungen im Nährstoffgehalt des Wassers, Veränderungen der Wassertemperatur oder Veränderungen in lokalen Strömungen waren bisher noch nicht Bestandteil der Forschung vor Pico.

Summary

For some cetacean species in the wild, social structure has been studied already: e.g. sperm whales (*Physeter macrocephalus*), pilot whales (*Globicephala* spp), killer whales (*Orcinus orca*) and bottlenose dolphins (*Tursiops truncates*). However, for the Risso's dolphin (*Grampus griseus*) social organization has not often been investigated yet due to its preference for and occurrence in offshore waters. In 2008, Hartman *et al*. were the first to analyze this further, working off the south coast of Pico Island, Azores where perfect research conditions for this species are present close to shore. This species is particularly suited for photo-ID research due to its unique body coloration pattern and distinct markings. The aim of the present study was to test whether the findings of 2008 are still valid with an enlarged data set and the handling of a much smaller sighting rate, which is similar to research in other species with other outcomes. To this end, the data which was used by Hartman *et al*. was reprocessed and analyzed together with an additional year of data. Using hierarchical clustering in R it was tested how far previous results are still applicable and how far they change when altering the used sighting rates. In addition, it was investigated by the means of one-way ANOVAs whether there are differences in the presence of the species in the research area between different months, seasons and years.

It was found that calculations with an enlarged data set fully support the findings of 2008. Risso's dolphin society has a complex social structure with a strong stratification along sex and age classes. Either very strong, stable, long-term groups are formed, dyadic associations or no associations at all, according to which sex and age class individuals belong to. The most stable associations were found among male adults and the loosest ones among subadults of both sexes. Female and calve clusters lay in between these two classes. Driving forces for cluster forming were differing between males and females. In the case of females, social support for calf care seems to be the predominant driving factor, while for males the main reason to form groups was access to fertile females. Moreover it was found that the use of a lower sighting rate slightly changed the outcomes. In general more clusters were defined as with a higher sighting rate and the social structure appeared to be more dynamic shifting more towards a fission-fusion society than to the clearly stratified structure found for Risso's dolphins in 2008. This supports the idea that the basis of their society trends indeed towards a fission-fusion model but is of a more complex structure due to the different needs of sex and age classes. Significant variations in the presence of the species could be found for all three cases: months, seasons and years. These variations lie mainly between spring/summer and autumn/winter months with higher abundance in the latter and between the first two research years and the last two. The whale watching activities taking place mainly in spring and summer in the study area are thought to have a rather high influence on this. What remains to be investigated are possible influences of environmental factors such as prey abundance, changes in nutrient content of the water, changes in water temperature or changes in upwellings and currents.

1. Introduction

The ecology and social organization of some wild cetaceans has been studied intensely, e.g. in sperm whales (*Physeter macrocephalus*; e.g. Whitehead 2003, Lettevall *et al*. 2002), pilot whales (*Globicephala* spp.; e.g. Ottensmeyer & Whitehead 2003, Heimlich-Boran 1993), killer whales (*Orcinus orca*; e.g. Bigg *et al*. 1990, Baird & Whitehead 2000) and bottlenose dolphins (*Tursiops truncatus*.; e.g. Gero *et al*. 2005, Chilvers & Corkeron 2002, Connor *et al*. 2001). Individuals in these species can be identified by the means of photo-identification on the basis of morphological characteristics. Using this method it is possible, after individual identification and a certain number of individual resightings over a longer period of time, to find out more about life history patterns. Therefore, long-term photo-identification can be the means to learn more about biological aspects of a species such as ecology, residency, social patterns etc..

According to Bräger (1999) usually group stability shows a negative correlation with body size, meaning it becomes more fluid in smaller species. Among the larger species stable, sometimes life-long, bonds are formed. Fission-fusion, as well as matrilineal societies, are known for example for bottlenose dolphins and, in the latter case, for killer whales (Connor *et al*. 2000, Shane *et al*. 1986). Also, in fission-fusion societies subgroups are known to often change in size and composition (Hartman *et al*. 2008). The associations here range from long-term stable alliances of male pairs and larger groups to less associated networks of males (Connor *et al*. 2000, Shane *et al*. 1986). In matrilineal societies, like in sperm whales, pilot whales and killer whales, the females, and in the latter case the males, often live in their natal pod throughout their life (Amos *et al*. 1993, Bigg *et al*. 1990, Whitehead & Weilgart 1990).

The aim of this study was to analyze association patterns of Risso's dolphins (*Grampus griseus*) over a four-year period (2004-2007) from a photo-identification study conducted around the south coast of Pico Island, Azores. The results are compared to the outcomes of Hartman *et al*. (2008). In addition to one year of extra data, resighting rates were altered from Hartman *et al*.'s procedure (2008), in order to find a possible change in association patterns depending on the number of resightings. To this end, the raw data consisting of photographs of the different sighted individuals were further processed for analysis with SPSS and R.

1.1. Study species

The Risso's dolphin belongs to the family Delphinidae. Adults of the species reach a length of 2.6-4m and weigh between 300-500kg (Reeves *et al*. 2008). The most noticeable difference to other dolphin species is their blunt head without a prominent beak and a distinctive V-shaped groove on the forehead (Reeves *et al*. 2008). The body shape is more robust in the front half than

in the back and the dorsal fin is one of the tallest in proportion to body length among any cetacean (Culik 2004). Between males and females there is just a small sexual dimorphism noticeable, although usually males appear a bit more muscular and longer in length with a slightly bigger melon (Hartman 2011, pers. comm.). The Risso's dolphin is a deep diver, mainly feeding on deep-water cephalopods (Cockroft *et al*. 1993) predominantly at night (Kruse *et al*. 1999). During the day their main behavior is travelling and socializing (Pereira 2008). The prey selection results in their preference for deep offshore waters. They are able to dive to a depth of 800m and stay under water for long periods of time, just as other teutophagous species (Whitehead 2003). As an evolutionary adaptation to their diet, there are just two to seven pairs of oval teeth in the front part of the lower jaw (Reeves *et al*. 2008). Information about the feeding ecology is mainly obtained from post-mortem examinations of stomach contents of dead animals and necropsies.

The Risso's dolphin has a wide distribution in almost all tropical and warm temperate waters around the globe, preferring deep waters near the continental slope and outer shelf (figure 1; Kruse *et al*. 1991, 1999). In general, they inhabit water depths of 400-1000m (Baird 2002, Jefferson *et al*. 1993, Ballance & Pitman 1998, Baumgartner 1997, Gannier 1998, Pereira 2008) and occasionally they are also found in some oceanic areas beyond the continental slope. They have a special liking for seamounts and escarpments because those are used by them to feed on

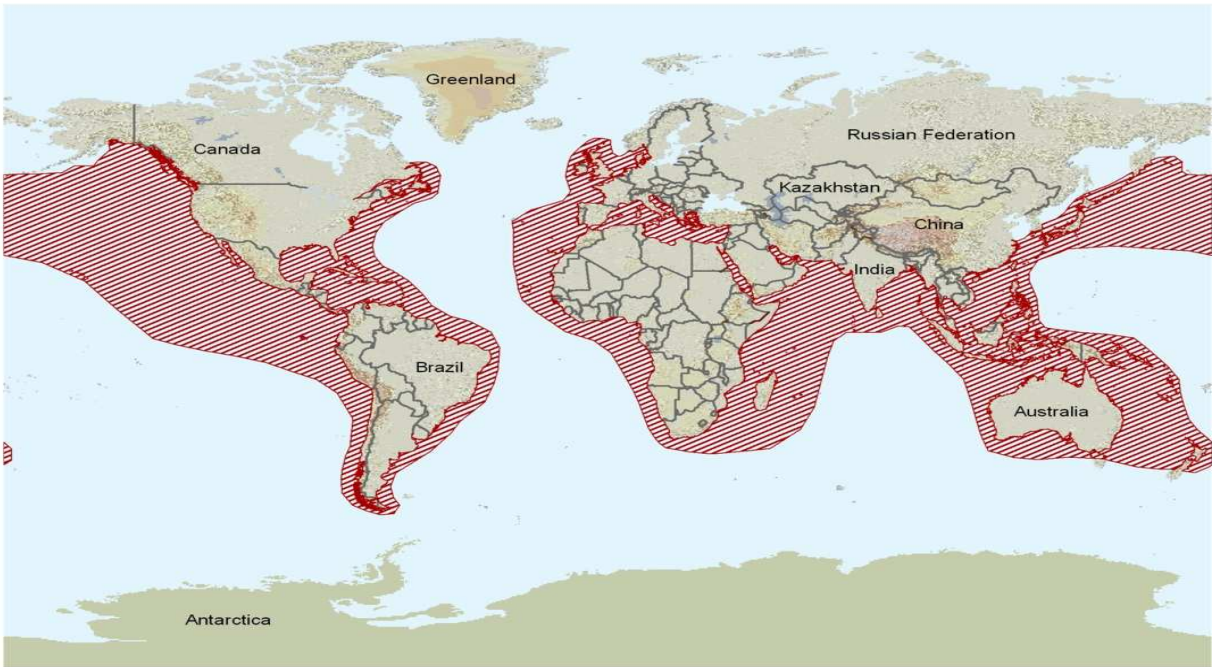


Figure 1: Risso's dolphin distribution (Taylor *et al.* 2008 in IUCN 2011)

upcoming and mesopelagic cephalopods occurring there (Taylor *et al*. 2008). Their distribution around the Azores seems also to be linked to the currents and upwellings found close to shore there which cause a local increase in productivity and therefore enhance feeding opportunities (Morton *et al*. 1998, Kruse *et al*. 1999, Visser *et al*. 2005). According to Kruse *et al*. (1999), long-term changes in the Risso's dolphin occurrence in some areas can be linked to changing oceanographic conditions and the, consequent, movements of their prey. These movements of cephalopods may cause summer inshore movement and certain site fidelity of individuals (Evans 1987, Leatherwood *et al*. 1980, Olavarría *et al*. 2001). However, according to Gaspari *et al*. (2007) there is little to no long-range dispersal between populations and no migratory patterns (Taylor *et al*. 2008). For the case of the Azores Hartman *et al*. (2008) state that there is a resident population existent around the south coast of Pico Island. Photo-identification data from the years 2004-2006 showed that one third of that resident population was sighted every year. This has also been reinforced by Pereira (2008) by the means of long-term opportunistic land-based observations around Pico Island from the years 1992-2005. Furthermore, several local population estimates have been done (e.g. Waring *et al*. 2007) but no worldwide data is available yet. The few reported group sizes range from one to several hundred individuals with a mean of 10-30 animals (Hartman *et al*. 2008, Leatherwood *et al*. 1980, Kruse *et al*. 1991, 1999, Pereira 2008). Although little is known about population trends, the IUCN ruled out a 30% global reduction over the next 60 years which classifies the species in the Least Concern category (IUCN 2011).

Perhaps the most obvious characteristic, and another difference to other dolphin species, is the species' skin coloration. In 1872, the first description of this particular feature was given by an anatomist about two examined dead Risso's dolphins, which had been bought at the London fish market. He noted that "*Perhaps the most noticeable external character was the very marked and peculiar coloration. The most prevalent tint was grey, varying in some parts of pure white and in other to deep black. The streaks or lines were of various length, running in all directions in a most fantastic manner, some parallel, some crossing each other and some forming sharp angles, zigzags and scribble-like patterns*" (Flower 1872). Calves, being about 1m in length, are born uniformly grey and become brownish-black when turning juveniles. As soon as they reach maturity and get involved in social interactions, they get the distinct white markings. This scarification pattern is caused by the teeth of other individuals, by confrontations with their prey and by confrontations with predators (MacLeod 1998). It is unique for every individual. The pattern on the dorsal fin provides a strong identification key for individual recognition. However, skin coloration also varies greatly between individuals, fading with age to a very pale grey or even white. However, the flippers and the fluke remain mainly dark throughout their life (Hartman *et al*. 2008).

In general, sexual dimorphism in Risso's dolphins is rather low. On average, males are slightly larger and heavier than females (Perrin & Reilly 1984). A differentiation between adult males and females can usually be made by virtue of the fact that males are often more muscular and of

a more robust built than females and have relatively more scars as well as a bulkier melon (Hartman *et al*. 2008). Admittedly, there are some exceptions to this rule with large, muscular and white females which are never accompanied by calves and therefore seem infertile (Hartman 2011, pers. comm.). Subadults are colored darkish brown and are never accompanied by calves. Calves are classified as being greyish brown in coloration and are maximally 75% the size of adults and are always escorted by adults (Hartman *et al*. 2008).

A broader picture about the Risso's dolphin social structure and their ecology is yet to be developed due to the fact that this species is usually hard to study in the wild because of their preference for deep, offshore waters. In 2008, Hartman *et al*. found that the social structure of the Risso's dolphin population off the south coast of Pico Island is structured in a stratified community which is based on highly associated social units separated along sex and age classes.

1.2. Aim of the study

The above mentioned findings by Hartman *et al*. (2008) provide the background within which this study was conducted. The data set was enlarged with one further year of photo-ID data and the following research questions were set to be investigated:

1. Are the findings of the study by Hartman *et al*. (2008) still supported after using an enlarged data base or do alterations occur?

2. Do the results from Hartman *et al*. (2008) change considerably, when a lower sighting rate is used additionally to the one in the original study?

3. Are there significant differences to be noticed in between months, seasons and years regarding the presence of Risso's dolphins in the study area?

For the question if the findings of the study by Hartman *et al*. (2008) are still supported using an enlarged data set it can be hypothesized that the previous results are indeed still valid. What can be expected is that, due to the enhanced data base, previous conclusions are likely to be strengthened. It is hypothesized that the findings of the present study will also show that male Risso's dolphins form long-term cluster pods of different sizes. Females form similar groups: they live in nursery systems together with their offspring. Subadults are mostly sighted in pairs. Those associations seem to be less firm and not as long lasting as the male cluster pods or the female nursery systems. Thus, also here, the expected conclusions are that Risso's dolphins live in a stratified community which differs from the matrilineal and fission-fusion societies being found in other cetacean species.

For the second question, how a lower sighting rate might change results, it is hypothesized that results might point more towards a fission-fusion society than clearly to the stratified society of Risso's dolphins found by Hartman *et al*. (2008). In their paper only identified individuals with a higher resighting rate than ten have been taken into account for the analysis. In order to investigate research question number 2, a sighting rate from ≥ two will be utilized. Lower sighting rates, thus also resighting rates, such as these are often found in research about other cetacean societies (e.g. Bräger *et al*. 1994, Slooten *et al*. 1993, Weinrich 1991, Whitehead *et al*. 1991, Würsing & Lynn 1996). Thus, a shifting of results toward a fission-fusion society seems more likely than with a higher sighting rate. This is because a lower sighting rate means a lower association rate, leading to a more dynamic social structure and possibly lower site fidelity.

Regarding the third question it is hypothesized that there are significant differences in the presence of Risso's dolphins to be found. Variations are likely for months, seasons and years. Influence is likely to come from the variations in workable hours spent at sea during the different times of the years. Also whale watching activity was already said to have an influence on the abundance.

2. Material and Methods

2.1. Study area

The archipelago of the Azores (Portugal), where this study was conducted, consists of nine bigger inhabited islands and several small rocks. They are situated between 37° till 39° North and 25° till 32° West (Tutin 1953, Bussmann 2010). With these coordinates they lie more or less directly on the Mid-Atlantic Ridge and all islands are of volcanic origin. Administratively they belong to Portugal and form a self-governed region of the country. However, their closest point to the mainland lies about 1500km away from it (Bussmann 2010; figure 2). The nine islands are divided into three groups: the Eastern Group (São Miguel and Santa Maria), the Central Group (Graciosa, Terceira, São Jorge, Pico and Faial) and the Western Group (Flores and Corvo). Those groups stretch out by almost 500km and are separated by deep waters (ca. 2000m) with scattered seamounts (Santos *et al*. 1995).
The vegetation nowadays consists of a variety of endemic and introduced species in contrast to its original state before the colonization of the islands, when most of the islands were densely forested (Bussmann 2010). In the coastal zones (0-200m) grasses, shrubs and flowering plants can be found. In the next zone (200-600m) meadows and pastures for the dairy cows extend, followed by a zone of the most original vegetation (600-1100m and above) mainly consisting of laurel forest, tree heath and mosses (Bussmann 2010).

The waters around the Azores are characterized by a high salinity, high temperature and a low nutrient regime (Johnson & Stevens 2000). This is due to a complex pattern of ocean circulation which is caused by the Gulf Stream, the North Atlantic and the Azores currents and their smaller side branches. The area constitutes a rich food oasis in the oligotrophic central North Atlantic due to the combination of the upwelling of nutrient-rich deepwater currents, the nutrient runoff from land and the complex and dynamic oceanic circulation patterns. It forms a habitat where coastal, pelagic and deep-water ecosystems can be found in close vicinity to each other, resulting in a species-rich and highly diverse marine ecosystem (Morton *et al*. 1998). Furthermore, the archipelago is characterized by steep submarine walls and a missing continental shelf (Morton *et al*. 1998). This creates a unique research opportunity not only for the present study species but for pelagic species in general which occur there close to shore where they find living conditions which normally can just be found further offshore.

Figure 2: Map of the Azores (www.graphicmaps.com 2011)

Due to the above named characteristics of the Azores, the archipelago forms a real cetacean hotspot of worldwide importance (Visser *et al*. 2005). Yearly over 24 species of resident and migrating whales and dolphins are observed in inshore waters (Sá 2006), some of which are severely endangered. This actually gives high indication that the area may form a critical habitat for cetaceans in the North Atlantic Ocean.

For this study the main research area was off the south coast of Pico Island (figure 3). Pico is, after São Miguel, the second biggest island of the Azores and situated at 38° 23´ till 38° 34´ North and 28° 02´ till 28° 32´ West (Bussmann 2010). At the eastern point of Pico an underwater bank stretches out for about 30km with a depth of just about 300 meters. Another bank like this, but shorter, can be found east of the village of Lajes do Pico in front of the Quiemada (Morton *et al*. 1998, Hartman 2011). These two banks act like a guiding system for currents into the bay of Ribeiras (also indicated by the dark grey area in figure 3). This, in combination with the relatively high runoff of nutrients from land in that area, creates a food-rich environment (Morton *et al*. 1998).

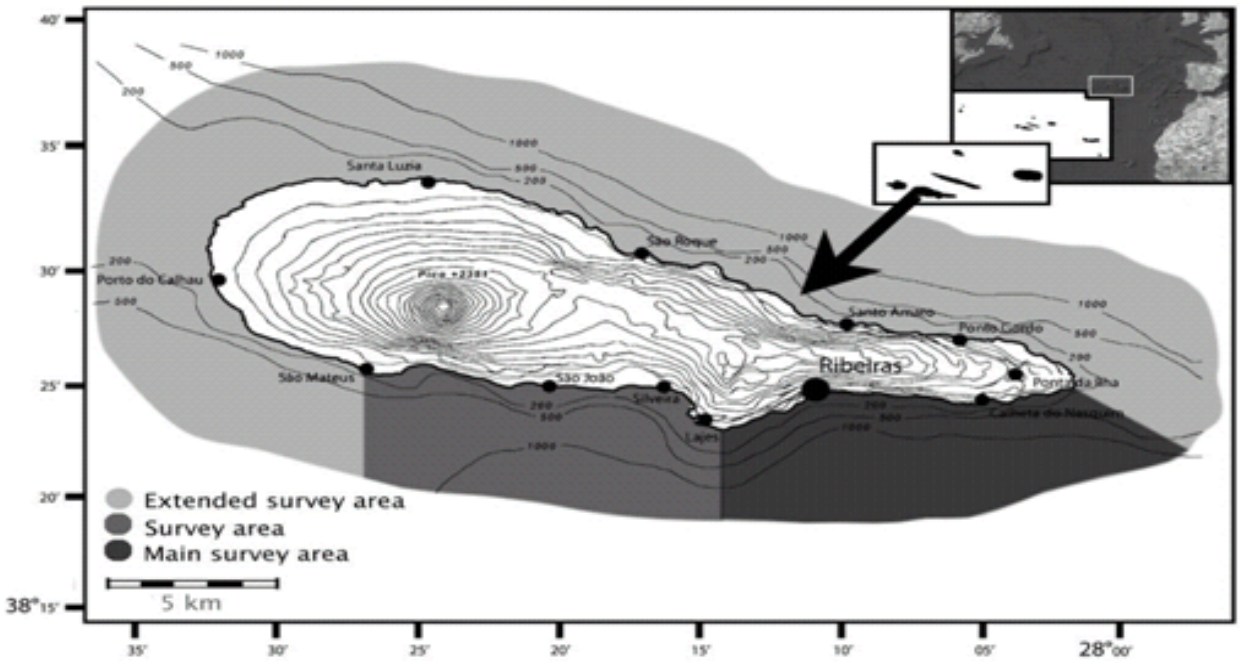


Figure 3: Pico Island, Azores, showing the main survey area and extended survey areas and 12 lookout points along the coast (Hartman 2011)

2.2. Field observations

Following the procedures of the study of Hartman *et al*. (2008), daily land-based surveys were made from a lookout point in Santa Cruz das Ribeiras 30m above sea level to spot Risso's dolphin presence in the main survey area (figure 3). These land-based surveys were extended with occasional observations from the other 11 lookout points distributed around the island's coast. Doing this enabled the whole coastal area of Pico to be covered (figure 3). For the land-based surveys 25mm × 80mm Observer binoculars (Steiner Binoculars, Bayreuth, Germany) were used.

Sea observations were carried out on a 7.2m Boston Whaler equipped with a Jetpac 150 horsepower diesel outboard waterjet engine. At sea, the main focus was always on photo-identification of all members of the present group. For this a Nikon D70 and a Nikon D200 with 70-300mm zoom lenses was used.

During the boat-based surveys either the last positions from the land-based surveys were used to find groups of Risso's dolphins back or the research vessel was guided directly by observers from land. Using these simultaneous observations on land and at sea, it was possible to get an overview of all present groups in the area. Most of the effort for both land- and boat-based surveys was concentrated in the bay of Santa Cruz das Ribeiras (also indicated by the main survey area in figure 3) since this part of the coast was the easiest to access from the field station situated there. Occasionally surveys around the whole island, which has about 110 km coast line (Bussmann 2010), were conducted (indicated by the lightest grey area in figure 3).

Effort time at sea ranged from May-October in 2004, April-September in 2005, April-October in 2006 and January-November in 2007 being mostly weather dependent.

Besides photo-identification effort, data collection at sea included continuous focal group follows as well as noting down group and behavioral characteristics (Altmann 1974, Mann 1999). Risso's dolphin group size was counted by at least two researchers at sea and later on determined from the photo-identification data. By these means it was overall possible to cover all Risso's dolphin groups in the area at a given time. Helpful in this is the fact that this species usually occurs in small groups which are usually characterized by a high degree of synchrony and calm surfacing (Hartman *et al*. 2008). According to Whitehead (2003) a group was defined as a sample of individuals that interacts socially and shows coordinated activity in its behavior. Following Hartman *et al*.'s procedure (2008), age classes of individuals, based on patterns of body coloration and body size, were used to determine group composition.

2.3. Photo-identification

While for most dolphins the shape of the trailing edge of the dorsal fin is the most diagnostic feature (Würsing & Jefferson 1990), Risso's dolphins show a range of coloration patterns according to different age classes over their whole body. Individuals can be recognized by their

individual scarification pattern and the shape of the dorsal fin together. These characteristic features make the method of photo-identification a practical means for individual identification of Risso's dolphins in order to find out more about their social structure and association patterns (Würsing & Jefferson 1990, Hartman *et al*. 2008).
Following the previously used technique from Hartman *et al*. (2008), dorsal fins were photographed for individual identification from the left and right side. For each research year over 400 photos were taken for each sampled group of Risso's dolphins. For the analysis only high quality pictures were used ($Q \geq 3$; Arnbom 1987). Further following the procedure of Hartman *et al*. (2008), all pictures of dorsal fins were cropped after enhancing the contrast with the autocolor function of Adobe Photoshop CS2 (version 9.0).
According to their scarification pattern individuals were classified into several age classes: adult male/female (AM/AF), adult unknown sex (AX), subadult unknown sex (SAX), calf (C). In order to be able to assign the calves later on to the females the calves were given the name-codes of their mothers plus a "c" attached at the end. Age classes were defined according to white body coloration and body size. Adults with at least one identified calf or a calf present were classified as females. In addition, recent DNA data provides proof about the sex of at least 86 resident individuals (Hartman, 2011, pers. comm.).
Due to the small sexual dimorphism described in chapter 1, a clear determination of the sex is rather difficult without clearly seeing the genital area or without having a DNA sample of that particular individual. However, the long-term observations of the animals provided a good insight in the sex of the different individuals and therefore errors in the sex identification are regarded as minute.

2.4. Analysis of associations

In order to determine association patterns and sighting, respectively resighting, rates of individuals, a group ID data base was created which was listing the composition of all groups by the time and date of the observation. In this data base, all animals photographed in the same group were regarded as being associated. An association was defined as at least "*two animals [...] if their circumstances (spatial ranges, behavioral states, etc.) are those in which interactions usually take place*" (Whitehead & Dufault 1999). The resighting rate was simply calculated by the sighting rate – 1.
For the determination of social structure patterns, both average-linkage and complete-linkage method for a hierarchical cluster analysis were used. Those methods are a way of calculating how big the distances between possible found clusters are. For both methods the definition according to Whitehead (2009) was used where for the average linkage method, also called unweighted groupmean, it is valid that*"[...] after A and B are merged [...]the similarity between AB and C is the average of all similarities between individuals in C and either A or B"*

(Whitehead 2009). For the complete linkage method, or furthest neighbor method, *"the similarity between AB and C is the least similar of AC and BC*" (Whitehead 2009).
The former was used to make the results comparable to the outcomes of Hartman *et al*. (2008), since they worked with the default setting of average-linkage in the Socprog program (Whitehead 2009). The complete-linkage method was used to rule out the possibility that associations are not found because of a very low index within or in between an associated group abolishing a very high index within or in between an associated group. Furthermore, differences in the outcomes between those two methods are also interesting to investigate.
In general, during a cluster analysis a clustering coefficient (CC) is calculated which measures the degree "*to which the associations of an individual are themselves associated in a binary network*" (Whitehead 2009). Thus, in order to answer research questions one and two the program R was used, calculating a hierarchical clustering analysis with the above mentioned data bases of all four research years for both sighting classes and both linkage methods. In R hierarchical clustering gives a distance value as the clustering coefficient instead of an association index with which Hartman *et al*. (2008) have worked. This distance also ranges from 0.0 to 1.0. A distance of 0.0 means that they have always been sighted together. Hence, it is comparable to an association index from the Hartman *et al*. (2008) paper of 1.0. Hartman *et al*. (2008) used the simple ratio index as association index because it was the default setting again in Socprog and recommended by the author (Whitehead 2009). In the present study the same relationship was calculated which is calculated with the simple ratio index: the ratio of sightings of two individuals together in relation to sightings with just one of the two individuals (Whitehead 2008). Thus, to make the outcomes comparable with the association index of Hartman *et al*. (2008) the clustering coefficient which is presented in the results is calculated by 1 – by R calculated distance. The dendrograms in appendix I-IV however, have to be read with having the distance value in mind. Hence, the CC in this study can be equated with the AI in the Hartman *et al*. (2008) paper and other cited literature. In general, the only difference between R and Socprog is that calculations in R are based on distances whereas other software, as Socprog, is based on similarities. Just the labeling of the axes in the dendrograms is basically inverted. For animals to be included in the analysis, resightings of identified individuals had to be separated by at least one day to rule out possible autocorrelations of sightings (Bejder *et al*. 1998). Following Bigg *et al*. (1990), a CC $\geq$ 0.5 was chosen above which associations were regarded as stable (thus for the distances the CC should be $\leq$ 0.5 but with the calculated similarities to compare it with the association index of the study from 2008 it stays $\geq$ 0.5). The association index was defined according to Cairns & Schwager (1987) as "*an estimate of the proportion of time that a pair of animals is in association*". The same differentiations applied by Hartman *et al*. (2008) between three types of associations have been set: clustered, paired, and not associated. The different types were defined as the following: clusters are groups of three or more individuals which are all associated among each other with a CC of at least $\geq$ 0.5. Further following Bigg *et al*. (1990), such clusters were used to define pods in case they were stable and formed on a long-term basis. A dyad of individuals was defined as a pair and pairs were not associated in clusters.

For any not-associated individual no form of association at all can be found with any other individuals. For strengthening the re-identification of animals, only individuals which have been seen a certain number of times are commonly included in the analysis (Bejder *et al*. 1998). In this study, following Hartman *et al*. (2008) again, only individuals with a sighting rate of at least ten times were included in the analysis in order to get a more robust data set than with lower sighting rates. In addition, only individuals were included in the analysis which had been identified from left and right side. Since the high used sighting rate excluded many individuals from the analysis, what for sure influenced the results, and also to test whether a lower sighting rate would change the results of Hartman *et al*. (2008) towards a more fission-fusion society of Risso's dolphins, an additional analysis was conducted handling a sighting rate of ≥ two sightings.

As an addition, in order to test for which linkage method the calculated dendrograms resembled the actual social structure best, or rather had a higher validity, the cophenetic correlation coefficient (CCC) was calculated. This coefficient is "*the correlation between the input distance measure among all pairs of subjects and the level at which they are joined on the dendrogram*" (Whitehead 2008, Bridge 1993). Its value ranges as well from 0 to 1. 1 indicates a perfect fit and 0 no relationship with the original data at all. According to Bridge (1993) a coefficient bigger than 0.8 is considered as an indication of a high validity of the calculated dendrogram. Thus, above 0.8 the dendrogram represents the raw input data in an acceptable way. The entire social structure analyses were performed using hierarchical clustering in R.

For testing whether there were significant differences to be noticed between months, seasons and years a one-way ANOVA was conducted in SPSS 15.0 for Windows (IBM® Corporation 2006) for each of the three cases. In order to test for whether the variables are normally distributed a Kolmogorov-Smirnov and a Shapiro-Wilks test were conducted with visualization in a normal Q-Q plot and a detrented normal Q-Q plot. In this test for normality the variable was the number of animals per month/season/year per hour at sea. For correcting for the non-normal distribution of the variables a common logarithm was used on the data sets of all three cases. Afterwards the transferred data was tested again for normal distribution with the above mentioned test and the same variable. A Levene's test was used to test for homoscedasticity with also using the same variable of number of individuals per month/season/year per hour at sea. Afterwards, a one-way ANOVA was run for respectively the presence of Risso's dolphins in all three cases. Here, the number of animals per month/season/year per hour at sea was used as dependent variable and the separate months/seasons/years as the independent variable. For multiple comparisons where differences might lie, a Tukey test was conducted with the same variables mentioned. All numbers of animal sightings were corrected for effort on sea (with hours spent at sea per month/season/year). Furthermore, it was calculated with the average number of Risso's dolphins per hour in order to minimize the chance of double sightings per day due to surveys in mainly the same area.

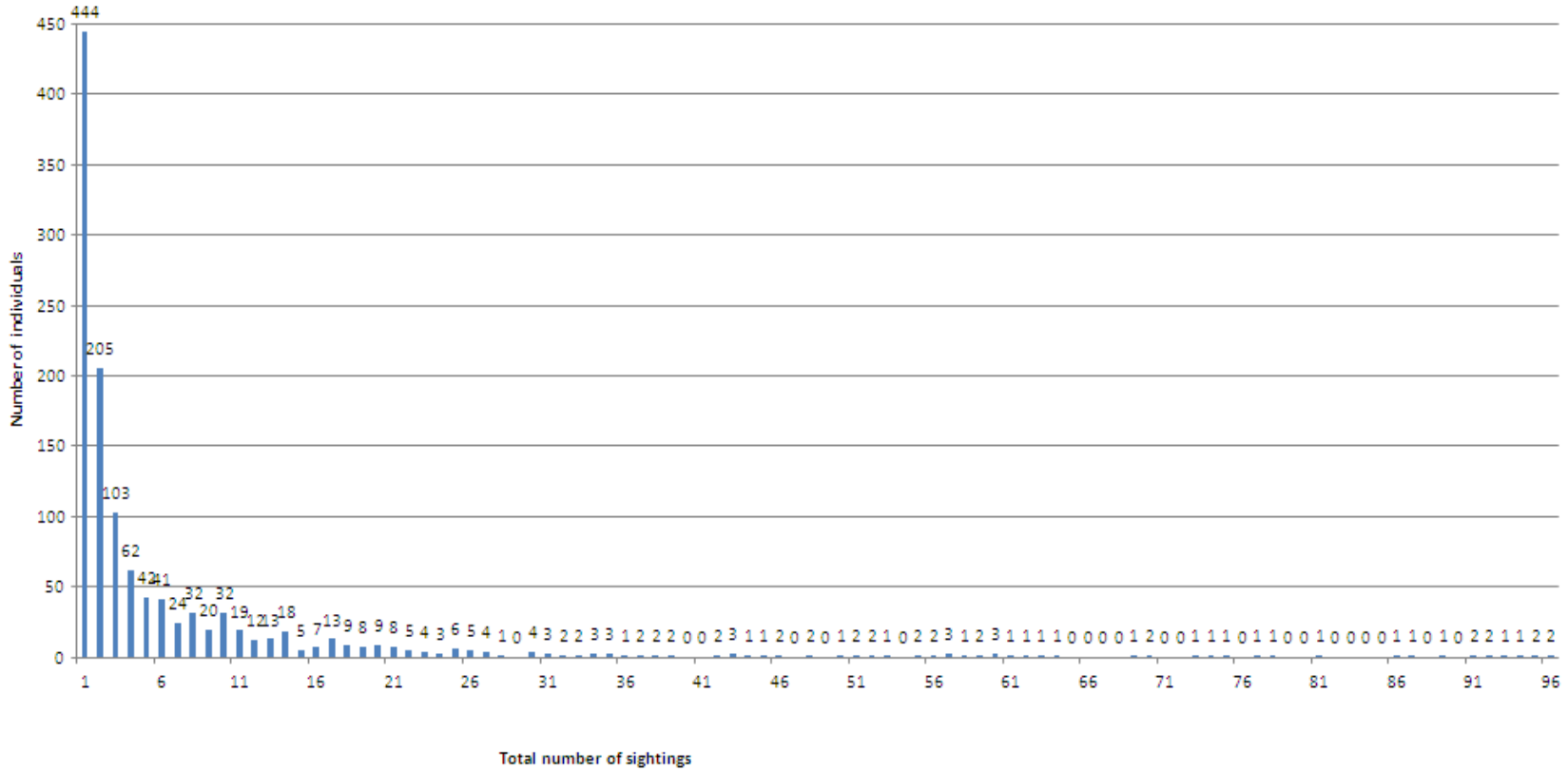
The p value used for every statistic test was 0.05.

3. Results

During the years 2004-2007 there were 338 days of fieldwork during which 823 groups of Risso's dolphins were sighted. The group size ranged from 1 to 63 individuals per group with a median group size of 9 animals (SD = 9.9). Working out the photo-identification data left 45605 high quality ID photographs (Q ≥ 3; Arnbom 1987). 100% of identification was achieved during 694 encounters (93%) out of a total number of 746 encounters.

3.1. Individual identification and sightings

A total of 9963 animals were sighted within the four years of the study. Out of these, 815 individuals are identified from both sides, 221 individuals are identified from the left side and 242 individuals are identified from the right side. This results in a maximum of 1278 (both sides + left side + right side) identifications possible and the minimum number of identifications of respectively 1057 (both sides + right side) and 1036 (both sides + left side).
The different sides were repeatedly matched separately and across by three individual researchers with the animals in the ID catalogue. This indicates just a small number of possibly unmatched pairs of identification photos, missed matches (indicating double counts) and mismatches (indicating underestimation).
As figure 4 shows the sighting number per individual for the four consecutive research years ranges from 1 to 96 (median=2; SD=14.65).


Number of individuals
Total number of sightings
444
205
103
62
42
41
32
32
24
20
19
18
13
13
12
9
9
8
8
7
6
6
5
5
5
4
4
4
3
3
3
3
3
3
2
2
2

Strong site fidelity can be observed: 64% of all individuals are resighted (figure 5), of which about 18% of all animals are seen ten times or more (9% of the animals for ≥ 10 times, 3% of the animals for ≥ 20 times, 6% of the animals for ≥ 30 times). A little bit over a third (36%) of all individuals is never resighted.

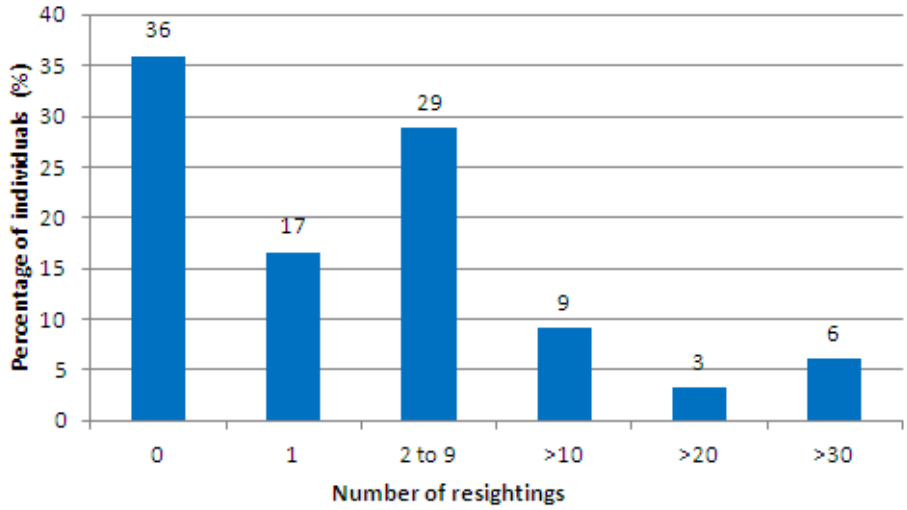


Figure 5: Frequency distribution of resightings of Risso's dolphins over the whole research period in the study area

As can be seen in figure 6, not all indentified individuals of the population are seen in every year. In 2004, 43% of the population is sighted (486 individuals), in 2005 it is 44% (498 individuals), in 2006 more than half of the population sighted with 52% (593 individuals) and in 2007, exactly 50% of the population is sighted (563 individuals).

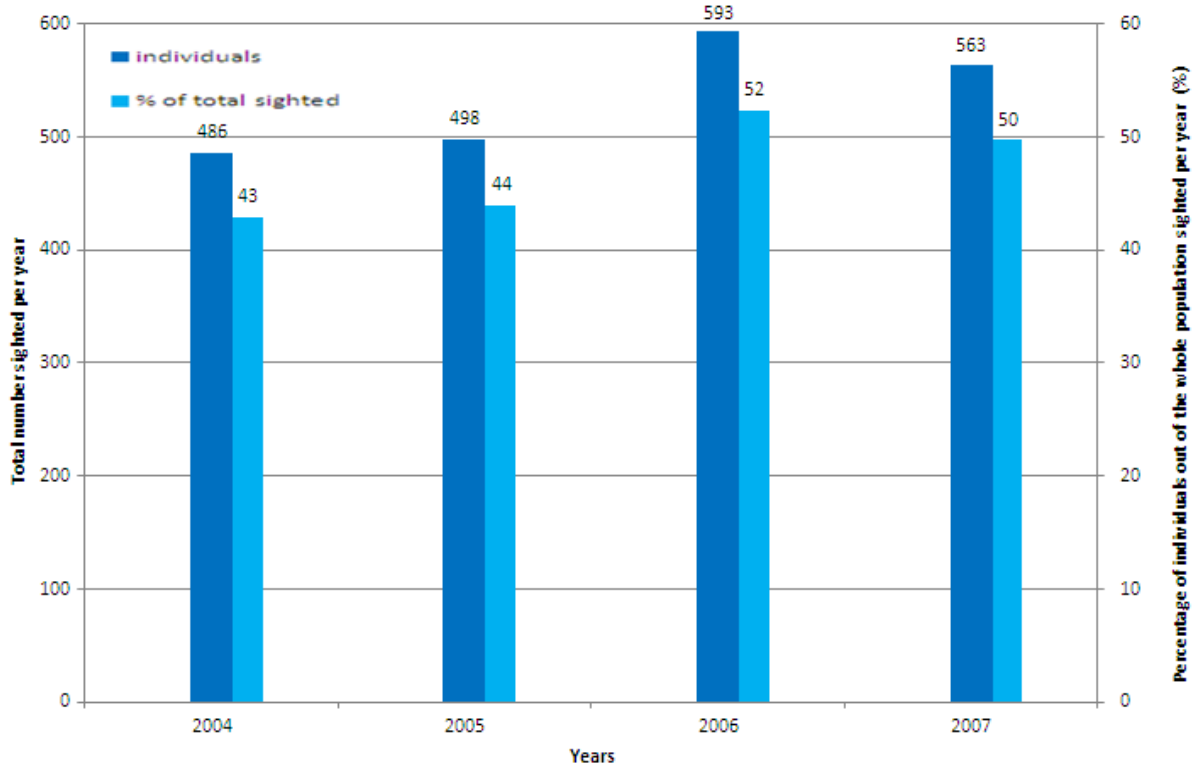


Figure 6: Total numbers and percentages out of the whole identified Risso's dolphin population sighted per separate year

3.2. Population size and structure of analyzed data set

To look at the rate in which new individuals enter the data set a slightly different approach was used than in the paper by Hartman *et al*. (2008). Here, the separate entering rates were looked at just for the individuals with whom the social structure analysis was done.

As can be expected in such a case, at the beginning the number of identifications increases rather quickly with a decreasing entering date over time (figure 7). In total, 869 animals, which were sighted more than twice, are identified in the four consecutive research years (table 1).

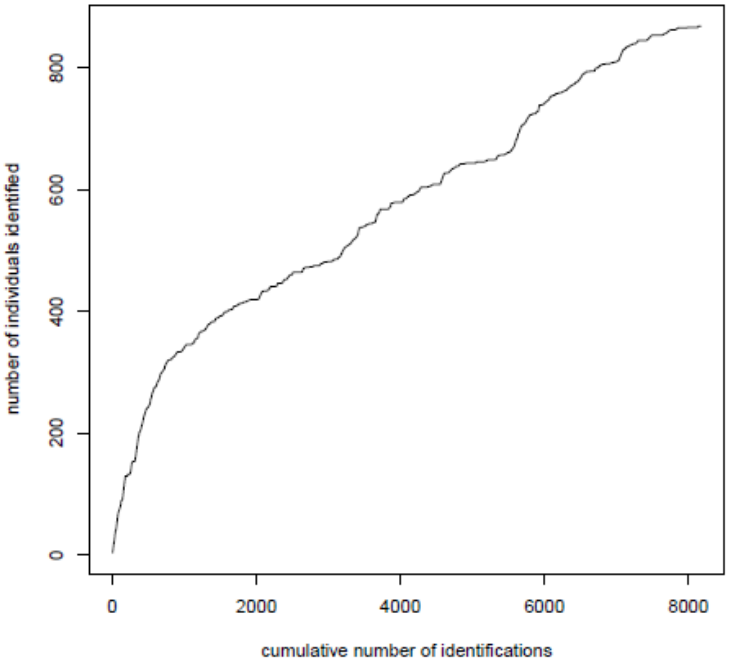


Figure 7: Number of identified Risso's dolphin individuals as a function of all cumulative identification for all identified individuals which have been sighted more than twice throughout the research period

As it shows in table 1, the biggest percentage of all identified individuals sighted at least twice, are adults and subadults of unknown sex (34%, respectively 20%). However, adult females and their calves (16% and 15%) are sighted more than adult males (14%).

Table 1: Age class composition of all identified individuals which have been sighted more than twice throughout the research period

Age class	Number of individuals	% of sex & age classes
Adult unknown sex	295	34
Subadult unknown sex	178	20
Adult male	124	14
Adult female	140	16
Calf	132	15
Total	**869**	

For the individuals sighted more than ten times, matters stand slightly different. In total, 328 animals were included in the analysis here (table 2). At the beginning the number of identified individuals also increases quite quickly. After about 200 individuals are identified, the entering rate of new identifications seems to decrease more than for the animals sighted more than twice (figure 8); the curve here flattens more.

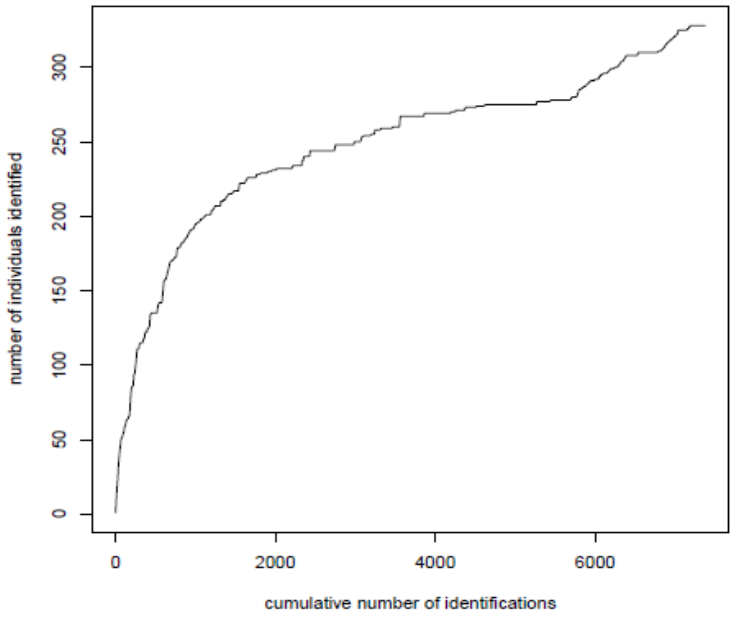


Figure 8: Number of identified Risso's dolphin individuals as a function of all cumulative identification for all identified individuals which have been sighted more than 10 times throughout the research period

For the individuals sighted more than ten times, table 2 shows that the biggest percentage of them consists of adults and subadults of unknown sex again (82% altogether). However, in this case this percentage is followed by adult males which also account for more than one third (35%) of the population. Adult females and their calves constitute a similar portion altogether (18%, respectively 11%) of the identified population taken for analysis in contrast to the individuals which were sighted more than twice.

Table 2: Age class composition of all identified individuals which have been sighted more than ten times throughout the research period

Age class	Number of individuals	% of sex & age classes
Adult unknown sex	96	29
Subadult unknown sex	23	7
Adult male	115	35
Adult female	59	18
Calf	35	11
Total	**328**	

Looking at the holistic data, table 3 shows that for the properly identified population that almost half of it consists of adults but with unknown sex (49%). One third is again subadults of unknown sex (30%). The percentages for adult females and males are very similar with 13% for the males and 12% for the females. The smallest part (10%) is formed by calves. Overall, one can see that by far the biggest part of the population consists of adults, regardless of whether sex is known or not.

Table 3: Age class composition of all identified individuals regardless of the number of sightings throughout the research period

Age class	Number of Individuals	% of total
Adult unknown sex	388	49
Subadult unknown sex	343	30
Adult male	145	13
Adult female	139	12
Calf	117	10
Total	**1132**	

That the biggest part of the population consists of adults also becomes clear when looking at figure 9. Here, the age class composition for all the separate years is shown in relation to the whole number of clearly identified individuals (n=1132). In every year, about 15% of the whole population consists of adults of unknown sex, adult males account for between 7% and 9% and adult females between 5% and 8%. Together this accounts for almost one third of the population. The subadults again are quite a big part in the population with percentages ranging from 9% to 11%. The rear end is again formed by the calves with percentages ranging from 3% to 6%. The calves have the biggest range during the years with double the percentage in 2006 than in 2004 and 2005.

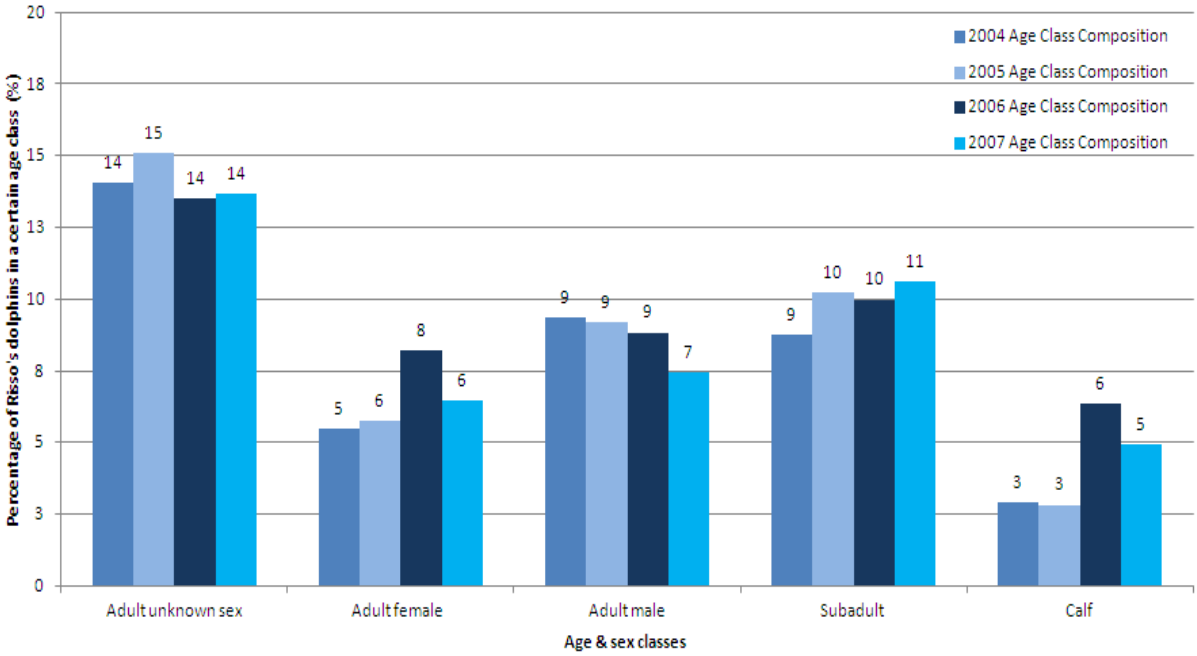


Figure 9: Percentage of different age classes sighted 2004-2007 in relation to the total number sighted (n=1132) throughout the whole research period

3.3. Associations

Analysis for social structure shows that the 328 different individuals who were sighted at least ten times form 875 units (not associated, pairs, clusters). For the 864 individuals who all were sighted at least twice, 595 units are found.

3.3.1. Average linkage method

Table 4 shows that most individuals sighted at least ten times are not associated (77%) when the average linkage method is used for analysis. The same is valid for the animals sighted at least twice (69%). Pairs are formed by 13% of the animals sighted at least ten times and by 19% of the ones sighted at least twice. Just 10% of all animals with higher sightings than ten times are found to be organized in clusters and just 12% of the individuals with at least two sightings.

For the individuals at least sighted ten times 70% of the adults are not found to be in any association. 20% of all those adults are organized in clusters and just 10% are found to form pairs. Mostly the subadults are also found not to be associated at all (74%). The remaining animals of their age class are evenly distributed between forming pairs or being organized in clusters (both with 13%). Almost half of the adult males are organized in clusters (46%). However, not much less of them are found not to be associated (40%). Only 14% of the adult males are found to be in pairs. Surprisingly, almost half of the adult females are not associated (49%). 29% of them are found in pairs and just 22% in bigger clusters. Calves are almost evenly distributed among all forms of possible associations: 34% of them are as well found not to be associated as also being organized in pairs. 31% of the calves are found to be in clusters. The outcomes for all individuals sighted at least twice are listed in the following. Again, the adults of unknown sex are found to be mostly organized in single units, therefore having no association at all (52%). A slightly higher percentage than for the animals sighted at least ten times is found to be in clusters (32%) and about one fifth (18%) live in pairs. Almost two third of the subadults (60%) are not associated at all. 23% are found to be organized in pairs and just 17% are living in clusters. More than half of the adult males (54%) live in clusters, over one third is however not associated (36%) and the remaining 10% are organized in pairs. Almost evenly distributed among being organized in pairs (39%) or living in clusters (38%) are the adult females. 23% of them are found not to be associated at all. Almost half of all calves (47%) of the ones sighted at least twice are living in clusters. About one third of them (32%) are organized in pairs and 21% are not associated.

Table 4: Social organization of individuals per age class for the average linkage method for both individuals with at least two sightings and individuals with at least ten sightings

	Individuals sighted ≥ 10 times					**Individuals sighted ≥ 2 times**				
Age class	Nr. of individuals	% of total individuals	Not associated (%)	Pairs (%)	Clusters (%)	Nr. of individuals	% of total individuals	Not associated (%)	Pairs (%)	Clusters (%)
Adult unknown sex	96	29	70	10	20	289	33	51	18	32
Subadult unknown sex	23	7	74	13	13	178	21	60	23	17
Adult male	115	35	40	14	46	124	14	36	10	54
Adult female	59	18	49	29	22	140	16	23	39	38
Calf	35	11	34	34	31	132	15	21	32	47
Total	**328**		**77**	**13**	**10**	**864**		**69**	**19**	**12**

3.3.2. Complete linkage method

Table 5 shows that most individuals sighted at least ten times are also not associated (76%). The same is valid for the animals sighted at least twice (68%). Pairs are formed by 14% of the analyzed individuals for at least ten sightings and by 20% of the ones sighted at least twice. For both options, clusters are formed in the least cases: by just 10% of the individuals at least sighted ten times and by 12% of the individuals at least sighted twice.

Among the individuals sighted at least ten times, in all the age classes most animals are not associated. The highest fraction is formed by subadults with 74% of them not being associated, closely followed by the adults of unknown sex with 71%. 41% of all adult males are not found associated and almost half of all females with 49%. A high 34% of no associations are found in the age class of the calves. On the contrary, they are found in pairs more than any other age class (37%). This is followed by the females, among which 21% are found in pairs. 16% of the adults males form pairs and among the adults of unknown sex and the subadults each form pairs for 13%. Clusters are formed mostly by adult males (43%). 29% of all calves are also organized in clusters, as well as 17% of both adult females and adults of unknown sex. Subadults are to be least found in clusters among all age classes (13%).
For the individuals sighted at least twice, the outcomes are the following. Here, also the subadults form the highest fraction (60%) of not associated animals. They are, as well, followed by the adults of unknown sex with 52%. Adult males here are higher with 37% than the adult females with just 23%. The smallest fraction of unassociated animals is formed by the calves with 21%. Pairs are again formed mostly by adult females (41%) and by the calves (34%). 25% of the subadults are found in pairs followed by 18% of all the adults of unknown sex and just 11% of the adult males. Clusters are formed by more than half of all adult males (52%). Also quite high percentages of cluster forming are found among adult females (36%) and calves (45%). 30% of the adults of unknown sex are organized in clusters and just 15% of all subadults.

Table 5: Social organization of individuals per age class for the complete linkage method for both individuals with at least two sightings and individuals with at least ten sightings

	Individuals sighted ≥ 10 times					**Individuals sighted ≥ 2 times**				
Age class	Nr. of individuals	% of total individuals	Not associated (%)	Pairs (%)	Clusters (%)	Nr. of individuals	% of total individuals	Not associated (%)	Pairs (%)	Clusters (%)
Adult unknown sex	96	29	71	13	17	289	33	52	18	30
Subadult unknown sex	23	7	74	13	13	178	21	60	25	15
Adult male	115	35	41	16	43	124	14	37	11	52
Adult female	59	18	49	21	17	140	16	23	41	36
Calf	35	11	34	37	29	132	15	21	34	45
Total	**328**		**76**	**14**	**10**	**864**		**68**	**20**	**12**

3.3.3. Cluster forming for average linkage method

Analysis of the identified individuals sighted at least twice defined 63 clusters above the marginal value of 0.5 for the CC. As can be seen in table 6, there are six clusters with a mean CC of 1.00. These clusters therefore can be regarded as the tightest formations of all of the identified ones. The mean CC of all identified clusters ranges from 0.67 to 1.00. Cluster size ranges from three to 17 individuals (mean = 4.75). What is striking is that five of the six clusters with the highest CC are among the ones with the lowest mean sighting rates. However, the clusters where strong site fidelity is indicated (high mean sighting number) still have a high CC above 0.9 (e.g. see clusters 8, 10, 11). In the composition of the clusters no real pattern can be found. However, many are composed of adult females and their calves (13 clusters; compare appendix I) with occasionally subadults or adults among them (nine clusters). Also, many clusters are solely composed of adults of unknown sex (11 clusters) and solely of adult males (ten clusters). There are ten clusters found where subadults are included, one group of just subadults and calves and one group solely composed of subadults. One cluster is also solely composed of calves. In total, six clusters are mixes of adults of unknown sex with either adult males (four clusters) or adult females (two clusters).

Very local clusters known from the field observations are s1, s2, s5, s6, s8 and s9 (clusters number 56, 10, 8, 62, 37 and 11). Their values for mean number of sightings throughout the whole research period also indicate strong site fidelity and all of them have a rather high mean CC.

Table 6: All clusters and their detailed information for the analysis with the average linkage method of all identified individuals sighted at least twice

Number of Cluster	Individuals	Size	Composition	Mean number of sightings	Mean CC
1	m50g, s34f, ub8a	3	AX	2.00	1.00
2	m5b, m5bc, s12a, s12c, s12e, s12f, s12g, s12h, s12i, s12j	10	AF, C, AX	2.00	1.00
3	s13b, s13c, s13d, s13e	4	AX	2.00	1.00
4	s15a, s15b, s15d, s15e	4	AX	10.00	1.00
5	s17a, s17b, s17c, s17d, s17e	5	AX	2.20	1.00
6	ub10a, ub10b, ub10d	3	AX	2.00	1.00
7	s31a, s31b, s31c	3	AM	17.67	0.97

8	s5a, s5c, s5d, s5e, s5f	5	AM	93.00	0.97
9	s32a, s32c, s32d	3	AX	7.67	0.94
10	s2a, s2b, s2c, s2f, s2g, s2i	6	AM	59.50	0.92
11	s9a, s9b, s9c	3	AM	94.00	0.92
12	m1a4, m1e4, m1e4c, m1x3, m1x3c, m1z3, m1z3c	7	AF, C	2.14	0.92
13	s25a, s25b, s25c, s25d, s25e, s25f, s25g	7	AX	4.14	0.90
14	m1x5, m1x5c, ub11a	3	AF, C, AX	4.67	0.90
15	m27f, s24a, s24b, s24d, s24e, s24f	6	SAX, AX	2.00	0.90
16	s3a, s3d, s3e, s3i, s3k, s3m	6	AM	2.33	0.90
17	m12c, m13k, m36c, m36d, m52b, m58h, m58i, m60b, m61b	9	SAX, AX	2.89	0.89
18	m1a5, m1a5c, m1f5, m1f5c, m1g4, m1g4c, m1g5, m1g5c, m1x4, m1x4c, m1y4, m1y4c, m1z4, m1z4c, m31hc, m50h, m50hc	17	AF, C	2.12	0.89
19	m1j3, m1j3c, m50a, ub7g	4	AF, C, AX, AM	2.25	0.89
20	s26a, s26b, s26c, s26d, s26e	5	AX	2.40	0.88
21	s16a, s16b, s16c, s16d, s16e	5	AM	19.40	0.87
22	ub1c, ub1d, ub1e	3	AM	28.67	0.86
23	m1w2c, m45k, m71i, s10a, s5d, ub1c	6	C, SAX, AX, AM	30.50	0.84
24	m1h3c, m45f, m46a, m46g	4	SAX, C	2.00	0.83
25	m1k, m1kc, m1mc	3	AF, C	2.33	0.83
26	m1u4, m1u4c, ub8g	3	AF, C, AX	2.33	0.83
27	m3c, m3d, m3e	3	AX	2.33	0.83
28	s19b, s19e, s19f, s4a, s4c, s4d, s4e, s4g, s4h	9	AX, AM	19.40	0.82
29	m1a6, m1a6c, m1d4, m1d4c	4	AF, C	3.00	0.81
30	m1c2, m1c2c, m1f2, m1f2c	4	AF, C	4.50	0.81
31	m1e6, m1e6c, m1q4, m1q4c	4	AF,C	2.50	0.81
32	m14c, m57c, m8b, s27f	4	AX, SAX	25.25	0.78

33	m25i, m58d, ub1f	3	SAX, AX	10.00	0.78
34	m58a, m64b, s25g, ub11g	4	SAX, AX	2.75	0.78
35	m25dc1, m34h, m34hc, m71b	4	AF, C, SAX	2.50	0.76
36	m1i4, m1i4c, m1m3, m1m3c, m29c, m29cc	6	AF,C	10.33	0.76
37	s8a, s8e, s8j, s8k, s8l	5	AM	73.60	0.75
38	m1j4, m1j4c, m1x, m1xc, m1y, m1yc	6	AF, C	10.17	0.75
39	m13g, m59e, s2c	3	AX, AM	25.67	0.75
40	m1dc2, m1s5c, m9bc	3	C	7.33	0.75
41	m1e, m1ec, m45c	3	AF, C, SAX	2.33	0.75
42	m1f6, m1f6c, m1xc, s1f, ub9i	5	AF, C, AM, AX	8.20	0.75
43	m1k5, m1k5c, m1y5, m1y5c	4	AF, C	4.75	0.75
44	m1z, m1zc, m57e	3	AF, C, AX	2.33	0.75
45	m22h, m8j, s11c	3	AX, SAX	20.67	0.75
46	m2bc, m3a, m53c	3	AM, AF, AX	13.33	0.75
47	m67e, s36b, ub11f	3	AX, SAX	4.00	0.75
48	m69h, m6i, m70a, m71i, ub1e	5	AX, SAX, AM	8.20	0.75
49	s18a, s18b, s18d	3	AX	2.67	0.75
50	s19g, s4b, s4f, s4i	4	AX, AM	10.50	0.75
51	s33a, s33b, s33e, s33h, s33i	5	AX	33.20	0.73
52	m30e, s12b, s21b, s21c	4	AF, AX	16.25	0.73
53	m1d2, m1d2c, m1l3, m1l3c	4	AF, C	7.50	0.72
54	m1o, m1oc, m1p, m1pc	4	AF, C	11.00	0.72
55	m13f, m23a, s15c	3	AX, AF	4.67	0.70
56	s1a, s1b, s1c, s1d, s1f, s1g, s1h	7	AM	24.14	0.70

57	m1i6, m1i6c, m1j6, m1j6c, m20cc1, m32fc, m69g, m70g, m71h	9	AF, C, AX, SAX	3.11	0.69
58	m1h, m1hc, m1j, m1jc	4	AF, C	5.25	0.69
59	s14f, s34b, ub9a	3	AM, AX	5.00	0.69
60	m1n3, m1n3c, m1o3, m1o3c, m1s4, m1s4c, m1t4, m1t4c, m2cc2	9	AF, C	11.11	0.68
61	m25c, m25e, ub1g	3	SAX, AF, AX	5.00	0.67
62	s6b, s6c, s6d, s6e, s6i, s6j	6	AM	88.50	0.67
63	m67h, m67i, m68a	3	SAX	2.33	0.67

AX = adult sex unknown;
AM = adult male;
AF = adult female;
SAX = subadult sex unknown;
C = calf
→ compare with the dendrogram in Appendix I

In table 7 the outcomes for the analysis for associations of all individuals sighted at least ten times can be seen. In total, 20 clusters were identified which have a mean CC above the marginal value of 0.5. Here three clusters are to be found with a mean CC of 1.0. In contrast to the outcomes above, all of those three also have a rather high mean number of sightings. The mean CC ranges from 0.64 to 1.00. Cluster size varies from three to nine individuals (mean = 4.5). Clusters where high site fidelity is indicated are s2, s5, s6, s8 and s9 (cluster numbers 7, 4, 20, 17 and 6). Those are as well, the local groups again. Although for those clusters high site fidelity can be seen, the mean CC is rather low for s6 and s8. A clearer pattern for the cluster composition can be seen here: half of the groups (ten clusters) are strict adult male groups followed in numbers by groups with adult females and their calves (four clusters). In contrast to the outcomes above, no subadults are found here in any cluster. Some clusters are a mix of adults of known and unknown sex (one for adult female and adult of unknown sex and two for adult male and adult of unknown sex). Just three clusters are solely composed of adults of unknown sex.

Table 7: All clusters and their detailed for the analysis with the average linkage method of all identified individuals sighted at least ten times

Number of Cluster	Individuals	Size	Composition	Mean number of sightings	Mean CC
1	m14c, m8b, s27f	3	AX	33.00	1.00
2	s10a, s5d, ub1c	3	AM	55.33	1.00
3	s15a, s15b, s15d, s15e	4	AX	10.00	1.00
4	s5a, s5c, s5d, s5e, s5f	5	AM	93.00	0.95
5	s31a, s31b, s31c	3	AM	17.67	0.92
6	s9a, s9b, s9c	3	AM	94.00	0.90
7	s2a, s2b, s2c, s2f, s2g, s2i	6	AM	59.50	0.89
8	s16a, s16b, s16c, s16d, s16e	5	AM	19.40	0.87
9	m1x, m1xc, m1y, m1yc	4	AF, C	11.25	0.84
10	ub1c, ub1d, ub1e	3	AM	28.67	0.83
11	m1o3, m1o3c, m1t4, m1t4c	4	AF, C	10.00	0.81
12	s19b, s19e, s19f, s4a, s4c, s4d, s4e, s4g, s4h	9	AX, AM	19.40	0.80
13	s1a, s1b, s1d, s1f, s1g	5	AM	27.40	0.75
14	m1l4, m1l4c, m1n3, m1n3c	4	AF, C	15.00	0.73
15	s33a, s33b, s33e, s33h, s33i	5	AX	33.50	0.73
16	m30e, s12b, s21b, s21c	4	AX, AF	16.25	0.72
17	s8a, s8e, s8j, s8k, S8l	5	AM	73.60	0.71
18	s19g, s4b, s4f	3	AX, AM	11.00	0.71
19	m1i4c, m1m3, m1m3c, m29c1, m29c	5	AF, C	10.60	0.70
20	s6b, s6c, s6d, s6e, s6i, s6j	6	AM	88.50	0.64

AX = adult sex unknown;
AM = adult male;
AF = adult female;
SAX = subadult sex unknown;
C = calf
→compare with the dendrogram in Appendix II

3.3.4. Cluster forming for complete linkage method

For the animals sighted at least twice, 62 clusters were identified using the complete linkage method. In table 8 it can be seen that the six clusters with the strongest CC are the same as in the outcomes for the same animals with the average linkage method. Again, five of the six have the low mean sighting rate of 2.00. The mean CC of all clusters ranges here from 0.69 to 1.00. Cluster size again varies from three to 17 individuals with a mean cluster size of 4.6. Clusters with indicated high site fidelity are for example s2, s5, s6 and s9 (see clusters number 10, 8, 38 and 13). Their mean CC is also still quite high being above 0.70. Again, no clear pattern in age class composition is detectable. Most groups are composed of adult females with their calves (15 clusters). Many clusters are also formed of solely adults of unknown sex (ten clusters) and of adult males (12 clusters). The rest of the clusters are composed of a mix of different age classes. What is striking is that over ten groups are also formed with subadults. Also one cluster solely consists of subadults and one solely of calves. One group is also found which has a composition of just calves and subadults.

Table 8: All clusters and their detailed information for the analysis with the complete linkage method of all identified individuals sighted at least twice

Number of Cluster	Individuals	Size	Composition	Mean number of sightings	Mean CC
1	m50g, s34f, ub8a	3	AX	2.00	1.00
2	m5b, m5bc, s12a, s12c, s12e, s12f, s12g, s12h, s12i, s12j	10	AF, C, AX	2.00	1.00
3	s13b, s13c, s13d, s13e	4	AX	2.00	1.00
4	s15a, s15b, s15d, s15e	4	AX	10.00	1.00
5	s17a, s17b, s17c, s17d, s17e	5	AX	2.20	1.00
6	ub10a, ub10b, ub10d	3	AX	2.00	1.00
7	s31a, s31b, s31c	3	AM	17.67	0.97
8	s5a, s5c, s5d, s5e, s5f	5	AM	93.00	0.97
9	s32a, s32c, s32d	3	AX	7.67	0.94
10	s2a, s2b, s2c, s2f, s2g, s2i	6	AM	59.50	0.92
11	m1a4, m1e4, m1e4c, m1x3, m1x3c, m1z3, m1z3c	7	AF, C	2.14	0.92
12	s25a, s25b, s25c, s25d, s25e, s25f, s25g	7	AX	4.14	0.90

13	s9a, s9b, s9c	3	AM	94.00	0.90
14	m1x5, m1x5c, ub11a	3	AF, C, AX	4.67	0.90
15	m27f, s24a, s24b, s24d, s24e, s24f	6	SAX, AX	2.00	0.90
16	s3a, s3d, s3e, s3i, s3k, s3m	6	AM	2.33	0.90
17	m12c, m13k, m36c, m36d, m52b, m58h, m58i, m60b, m61b	9	SAX	2.89	0.89
18	m1a5, m1a5c, m1f5, m1f5c, m1g4, m1g4c, m1g5, m1g5c, m1x4, m1x4c, m1y4, m1y4c, m1z4, m1z4c, m31hc, m50h, m50hc	17	AF, C	2.12	0.89
19	m1j3, m1j3c, m50a, ub7g	4	AF, C, AX, AM	2.25	0.89
20	m1x, m1xc, m1y, m1yc	4	AF, C	11.25	0.88
21	s26a, s26b, s26c, s26d, s26e	5	AX	2.40	0.88
22	s16a, s16b, s16c, s16d, s16e	5	AM	19.40	0.87
23	ub1c, ub1d, ub1e	3	AM	28.67	0.86
24	m1i6, m1i6c, m1j6, m1j6c, m32fc	5	AF, C	3.00	0.86
25	m1w2c, m45k, m71i, s10a, s5d, ub1c	6	C, SAX, AM	30.50	0.84
26	m1h3c, m45f, m46a, m46g	4	C, SAX	2.00	0.83
27	m1k, m1kc, m1mc	3	AF, C	2.33	0.83
28	m1u4, m1u4c, ub8g	3	AF, C, AX	2.33	0.83
29	m3c, m3d, m3e	3	AX	2.33	0.83
30	s4b, s4f, s4i	3	AM	10.67	0.83
31	s19b, s19e, s19f, s4a, s4c, s4d, s4e, s4g, s4h	9	AX, AM	19.40	0.82
32	m1a6, m1a6c, m1d4, m1d4c	4	AF, C	3.00	0.81
33	m1c2, m1c2c, m1f2, m1f2c	4	AF, C	4.50	0.81
34	s1a, s1b, s1d, s1f, s1g	5	AM	27.40	0.80
35	m14c, m57c, m8b, s27f	4	AX, SAX	25.25	0.78
36	m25i, m58d, ub1f	3	SAX,	10.00	0.78

			AX		
37	m58a, m64b, s25g, ub11g	4	SAX, AX	2.75	0.78
38	S6b, s6d, s6i	3	AM	89.67	0.76
39	m25dc1, m34h, m34hc, m71b	4	AF, C, SAX	2.50	0.76
40	m1i4, m1i4c, m1m3, m1m3c, m29c, m29cc	6	AF, C	10.33	0.76
41	s6c, s6e, s6j	3	AM	87.33	0.76
42	m1d2, m1d2c, m1j4, m1j4c	4	AF, C	7.00	0.75
43	s8a, s8e, s8j, s8k, s8l	5	AM	73.60	0.75
44	m13g, m59e, s2c	3	AX, AM	25.67	0.75
45	m1dc2, m1s5c, m9bc	3	C	7.33	0.75
46	m1e, m1ec, m45c	3	AF, C, SAX	2.33	0.75
47	m1f6, m1f6c, m1xc, s1f, ub9i	5	AF, C, AM, AX	8.20	0.75
48	m1z, m1zc, m57e	3	AF, C, AX	2.33	0.75
49	m22h, m8j, s11c	3	AX, SAX	20.67	0.75
50	m2bc, m3a, m53c	3	AM, AF, SAX	13.33	0.75
51	m32f, m69g, m70g	3	AF, AX, SAX	8.00	0.75
52	m67e, s36b, ub11f	3	AX, SAX	4.00	0.75
53	m69h, m6i, m70a, m71i, ub1e	5	AX, SAX, AM	8.20	0.75
54	s18a, s18b, s18d	3	AX	2.67	0.75
55	m20cc1, m62h, m71h	3	C, SAX	4.67	0.74

56	m1n3, m1n3c, m1o3, m1o3c, m1t4, m1t4c, m2cc2	7	AF, C	11.71	0.74
57	s33a, s33b, s33e, s33h, s33i	5	AX	33.20	0.73
58	m1e6, m1e6c, m1q4, m1q4c, m1y5, m1y5c	6	AF, C	2.67	0.73
59	m30e, s12b, s21b, s21c	4	AX, AF	16.25	0.73
60	m1o, m1oc, m1p, m1pc	4	AF, C	11.00	0.72
61	m13f, m23a, s15c	3	AF, AX	4.67	0.70
62	m1h, m1hc, m1j, m1jc	4	AF, C	5.25	0.69
AX = adult sex unknown; AM = adult male; AF = adult female; SAX = subadult sex unknown; C = calf →compare with the dendrogram in Appendix III					

In table 9 the outcomes of the analysis with the complete linkage method of all individuals sighted at least ten times can be seen. 19 clusters were defined in total. Again, the same three clusters as above have the highest mean CC of 1.00 with also a rather high mean sighting rate. The mean CC ranges from 0.72 to 1.00 which is higher than for the outcomes of the same individuals with the average linkage method. Mean cluster size is 4.2 with, again, a range from three to nine individuals. Indicated clusters with high site fidelity are s2, s6 (split up in two subgroups), s8 and s9 (see clusters number 7, 16 and 19, 14 and 6). More than half of the clusters (11 clusters) are composed solely of adult males. Four clusters are formed by adult females and their calves. Three of the clusters are composed of adults of unknown sex and just one group is a mix of those and adult males.

Table 9: All clusters and their detailed information for the analysis with the complete linkage method of all identified individuals sighted at least ten times

Number of Cluster	Individuals	Size	Composition	Mean number of sightings	Mean CC
1	m14c, m8b, s27f	3	AX	33.00	1.00

2	s10a, s5d, ub1c	3	AM	55.33	1.00
3	s15a, s15b, s15d, s15e	4	AX	10.00	1.00
4	s5a, s5c, s5d, s5e, s5f	5	AM	93.00	0.95
5	s31a, s31b, s31c	3	AM	17.67	0.92
6	s9a, s9b, s9c	3	AM	94.00	0.90
7	s2a, s2b, s2c, s2f, s2g, s2i	6	AM	59.50	0.89
8	s16a, s16b, s16c, s16d, s16e	5	AM	19.40	0.87
9	m1x, m1xc, m1y, m1yc	4	AF, C	11.25	0.84
10	ub1c, ub1d, ub1e	3	AM	28.67	0.83
11	m1o3, m1o3c, m1t4, m1t4c	4	AF, C	10.00	0.81
12	m1i4c, m1m3, m1m3c	3	AF, C	10.33	0.80
13	s19b, s19e, s19f, s4a, s4c, s4d, s4e, s4g, s4h	9	AX, AM	19.40	0.80
14	s8e, s8j, s8k, s8l	4	AM	72.75	0.76
15	s1a, s1b, s1d, s1f, s1g	5	AM	27.40	0.75
16	s6b, s6d, s6i	3	AM	89.67	0.75
17	m1l4, m1l4c, m1n3, m1n3c	4	AF, C	15.00	0.73
18	s33a, s33b, s33e, s33h, s33i	5	AX	33.50	0.73
19	s6c, s6e, s6j	3	AM	87.33	0.72

AX = adult sex unknown;
AM = adult male;
AF = adult female;
SAX = subadult sex unknown;
C = calf
→compare with the dendrogram in Appendix IV

3.3.5. Cophenetic correlation coefficient

The outcomes for the cophenetic correlation coefficients are the following. As can be seen in table 10, for both, at least two sightings and at least ten sightings, the coefficients are higher for the average linkage method than for the complete linkage method. For the analysis of the animals with at least ten sightings the difference between both outcomes is slightly bigger than for the animals with at

least two sightings. Since all values of the different methods are above the marginal value of 0.8 mentioned by Bridge (1993), it indicates that all dendrograms, respectively analyses, represent a good display of the actual state of the associations of the Risso's dolphins.

Table 10: Cophenetic correlation coefficient per sighting class per method

Method	CCC
Animals sighted at least 2 times_Average Linkage Method	0.89
Animals sighted at least 2 times_Complete Linkage Method	0.82
Animals sighted at least 10 times_Average Linkage Method	0.94
Animals sighted at least 10 times_Complete Linkage Method	0.88

3.4. Presence in different months, seasons and years

Regarding the differences between the months in respect to the presence of Risso's dolphins, a significant difference ($p < 0.001$; $df = 10$) was found. However, there are no equal data sets for all months. Also for the winter months, the data is completely missing for some years. For the month March, there is no data at all available (figure 10). With further investigation using the Tukey test to find out where the differences lie exactly, no significances are found. The only two differences which occur and which could be regarded as marginally significant are between April and November ($p = 0.088$) and between May and July ($p = 0.085$). Thus, these results indicate no big differences between the months in general.

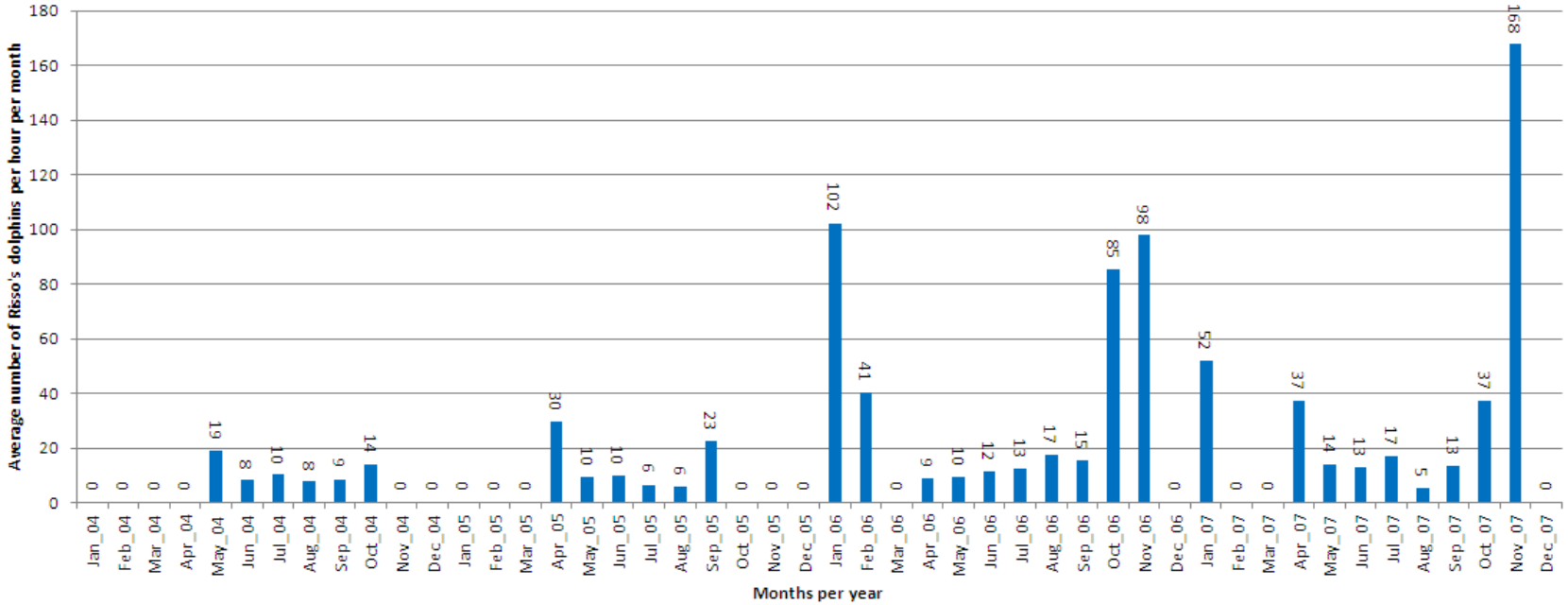


Figure 10: Average number of Risso's dolphins per hour per month throughout the research period

In looking at the different months, the question arrises as to wether there are some differences to be found regarding the seasons. A visualization of the sighted Risso's dolphins per hour per season is shown in figure 11. In winter there are about ten animals sighted per hour, in spring this number is lower with around four as well as in summer with around three. The highest number of animals sighted per hour is in autumn with 23 Risso's dolphins per hour.
There are actually siginificant differences detected when conducting the one-way ANOVA ($p < 0.001$; $df = 3$). The more detailed look with the post hoc test revealed that the average number of sightings per hour per season differs significantly from winter to spring ($p = 0.046$), spring to summer and autumn ($p = 0.014$; $p < 0{,}001$) and, as well, marignally from summer to autumn ($p = 0.073$). The seasons are defined as winter = January till March, spring = April till June, summer = July till September and autumn = October till December. These definitions are set in accordance with previous work by the Nova Atlantis foundation with this data.

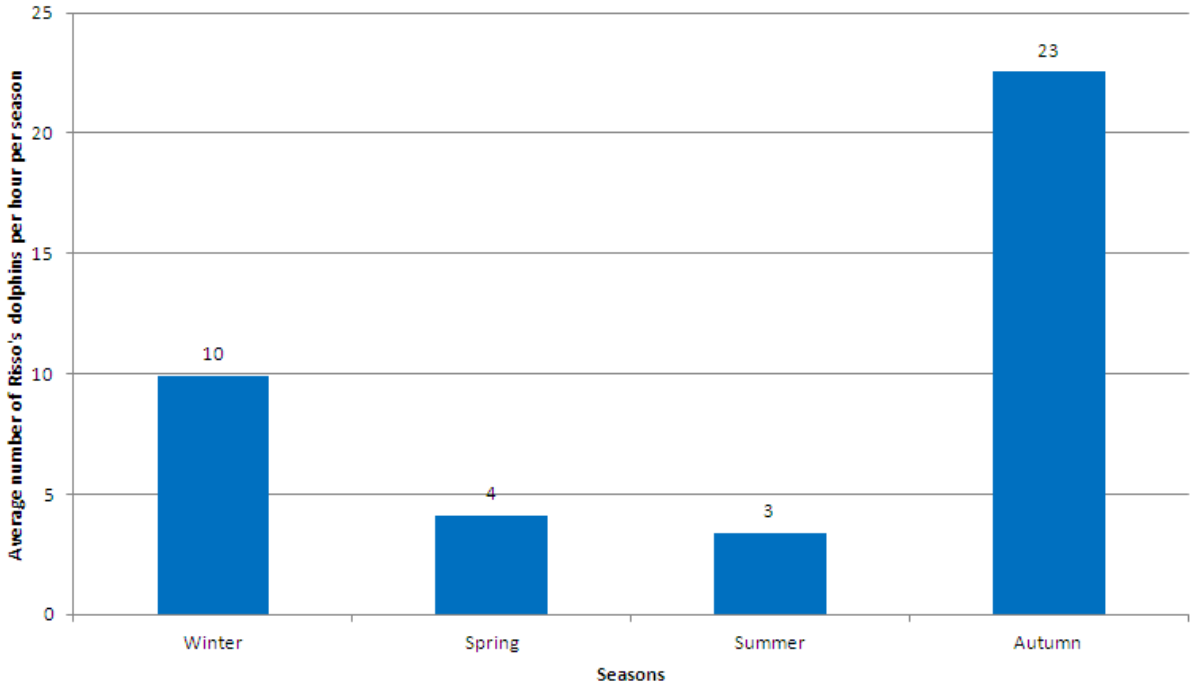


Figure 11: Average number of Risso's dolphins per hour per season throughout the research period

As figure 12 shows, most Risso's dolphins per hour were sighted in 2006, followed by 2007. Least individuals were seen in 2004. The two first years, 2004 and 2005, were actually very similar regarding the sightings. However, also for the presence between the years a significant difference was found ($p = 0.029$; $df = 3$), which lies between the years 2005 and 2006 ($p = 0.015$).

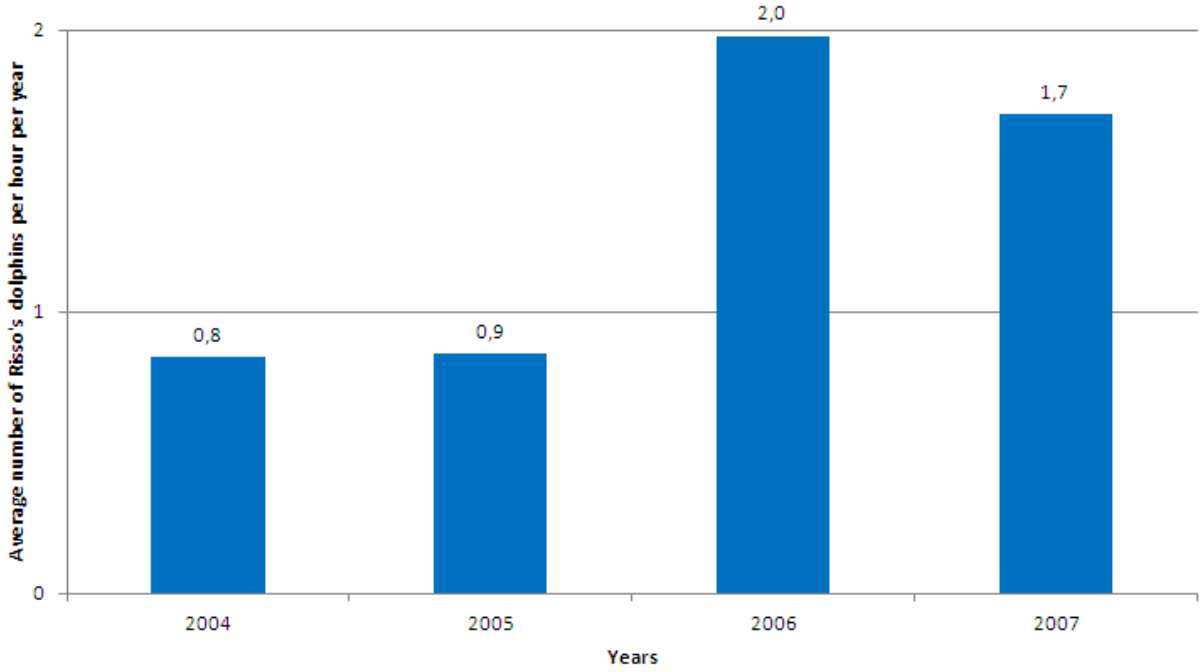


Figure 12: Average number of Risso's dolphins per hour per year throughout the research period

4. Discussion

In the present study, logically, with 108 more field days at sea (n = 338), more encounters of Risso's dolphins took place than in the study of 2008. The median group size was a bit smaller with nine instead of 13 individuals than in the study by Hartman *et al*. (2008). This indicated smaller groups in general. The range of sighting number per individual also went up a bit from 61 to 96, which is to be expected using more data. However, the median sighting number stayed the same with 2.0 as in the previous study from 2008.

4.1. Identification and sightings

1% more than in the period from 2004 to 2006 was resighted with the additional data of year 2007 included. Each year, quite a high proportion of the whole identified population was always sighted (figure 6 in chapter 3). This fact and the partially high numbers of sightings (up to over 90 times for some groups) for the whole research period indicate strong site fidelity for at least part of the population. Site fidelity in general is the tendency of an animal to return frequently to a previously occupied area over a longer period of time (Baird *et al*. 2008, Defran & Weller 1999, McSweeney *et al*. 2007). There were also lower mean sighting rates for all four research years found. Different studies however, used such low numbers of sightings to conclude certain site fidelity already for other dolphin species (e.g. Baird *et al*. 2008, Defran & Weller 1999). In this study, it seemed reasonable to use a mean sighting number of ≥ ten for all four research years as an indication for site fidelity: this accounts for a little less than 20% of the whole population. Also, the thought of rather high site fidelity is confirmed by the raw data. In addition, Baird *et al*. (2008) state that frequent within- and in between year sightings are a strong indication for this which was also the case in this study. High site fidelity could be explained by several factors. As mentioned in chapter 1, there is likely to be increased productivity in close proximity to the islands of the Azores archipelago, including upwellings because of the steep underwater slopes and nutrient input from freshwater runoff from land. Such increased productivity can cause spatial and temporal predictability of prey (Baird *et al*. 2008, McSweeny *et al*. 2007), which in this study could also account for the formation of fixed clusters of the study species. Cluster formation is further elaborated upon later in the present report.

4.2. Population size

Although figure 7 and 8 in chapter 3 do not show it clearly, it can be stated that a population size larger than 1028 exists. For these analyses an overall n of 1132 was used and the growth curve of the population is still increasing. Also the possible minimum number of identifications according to the photographic data points to this. Whether a population is healthy can never be clearly defined because the "*size is not universal and is widely assumed to be strongly dependent on details of the biology and environment and the types of threats faced*" (Frankham *et al*. 2004). For such conclusion in this study there is not enough known

yet about the Risso's dolphin population off Pico. However, looking at the values given for required population sizes to constitute a viable population that can overcome different threats (Frankham *et al*. 2004), it can be estimated that, with expected further identifications to come, the Risso's dolphin population around Pico Island at least seems to be stable and healthy. Also the sex ratios in tables 1 and 2 support this estimation.

4.3. Associations – Differences among average linkage and complete linkage method

The reason why both linkage methods, average linkage method and complete linkage method, were used is because the average linkage method was set as a default in the SOCPROG program which was used for the calculations in the study of Hartman *et al*. (2008). As already mentioned the average linkage method calculates that the "*similarity between cluster AB and C is the average of all similarities between individuals in C and either A and B*" (Whitehead 2008). It is also called "unweighted group mean cluster analysis". Taking the average between two points meant that some associations could be overlooked: for example a point with the association index 0.0 and a point with the association index of 1.0 in the same cluster (so no association and a very strong association) would result in 0.5 which in this study was chosen as the threshold value. This does not happen when using the complete linkage method for the cluster analysis. This method is also called "furthest neighbor cluster analysis". Here the "*similarity between AB and C is the least similar of AC and BC*" (Whitehead 2008). Therefore, overlooking strong associations, which could happen with the average linkage method, does not happen here: all strong or weak linkages are noticed. This was regarded as a valuable characteristic in this study. However, according to Milligan & Cooper (1987) and Whitehead (2008), the average linkage method should generally be preferred in the study of social structure. The reason given for this is that extreme distances (large or small) caused by, either, random measurement error or other possible errors have less impact on the results than when using other linkage techniques (Whitehead & Dufault 1999). According to the authors, it reflects the relationships among the input data in a better way (Milligan & Cooper 1987, Whitehead & Dufault 1999). Admittedly, the differences between both methods were found minute in the present study.

A means of testing which one of the two methods used fits best for reflecting the relationships in the input data is to calculate the cophenetic correlation coefficient (CCC). This coefficient is a value between 0 and 1 for how authentically a dendrogram of the calculated clusters with their clustering values maintains the original relationships between the original data points in the raw data. A coefficient value of 1 means the dendrogram is a perfect resemblance of the actual relationships whereas a value of 0 indicates no resemblance at all (Whitehead 2008). As visualized in table 10 in chapter 3 the CCC was slightly higher for both calculations with the average linkage method than with the complete linkage method. According to Bridge (1993) a dendrogram is a reasonable visualization of a data matrix if the CCC is greater than 0.8. This was indeed the case for all outcomes of both calculations.

However, according to Leisch (2011, pers.comm.) the fact that the CCC fits better for the average linkage method is not surprising because it is, in its definition's characteristics, closer

to the definition of the average linkage than to the complete linkage method. Making use for example of the so called agglomerative coefficient (another value for the same problem) would change the outcomes towards the complete linkage method producing better fitting dendrograms. Admittedly, in this case the differences between the CCC outcomes for both methods appear negligible. Both methods produced a well fitting depiction of the original data. This can also be noticed looking at the cluster formations in tables 6 to 9 in chapter 3. As can be seen in the analysis for all animals sighted ≥ ten times there are just very small differences in both outcomes. Cluster 12 of the outcomes of the complete linkage method can be found in cluster 19 in the outcomes of the average linkage method with two additional animals. Cluster number 16 and 18 in the average linkage outcomes are extra and cluster number 17 has one additional animal of the s8 pod in comparison to the outcomes of the complete linkage method. Furthermore, in the complete linkage outcomes, the s6 cluster (cluster number 20 in the average linkage outcome) is split up into two clusters of the size of three instead of one group with six individuals. These very close outcomes are reflected in the very alike CCC. The reason why some groups are missing or split up further in the complete linkage outcomes is that the criteria in this method are stricter (Leisch 2011) as can also be seen in the definition of the two methods. Instead of taking the average of a whole group, the actual distances, respectively similarities, in the clusters are taken into account. This was also noticeable in the data when calculating the mean clustering coefficient (CC) for tables 6 to 9 in chapter 3. This was done by having the range of all CCs of the individuals within the found clusters. For the average linkage method, one animal often was slightly below the 0.5 marginal value which was used for this analysis. Nevertheless, it was decided to include these individuals and these clusters in the results because they give proof of the differences between the two methods which also needed to be shown and compared. For the complete linkage method all individuals are above or right on the marginal value for the CC.

This minute difference is also visible when looking at the range of mean CCs of both methods: the CCs of the complete linkage method are slightly higher with a range from 0.72 till 1.0 in contrast to 0.64 to 1.0 for the average linkage method. Smaller ranges in the latter case were produced by the individuals lying below the marginal value. Occasionally the clusters have a slightly changed sequence regarding the mean CC value. This is also due to the ranges of CCs of all the individuals creating the mean CC for a cluster. For the analysis of the animals sighted ≥ two times the picture looks similar. Most clusters are very similar. However, for both outcomes there are again clusters which are not included in the outcomes for the other method (see cluster number 38, 43, 50, 53, 59 and 61 for the average linkage method and cluster number 20, 30, 42 and 51 for the complete linkage method). Also clusters with the same core-composition but more or fewer individuals are detected again, like clusters 56 (average linkage) and 34 (complete linkage), with a difference of two more individuals for the average linkage method. Also, cluster 57 (average linkage) is five animals bigger than cluster 24 (complete linkage). A difference of two individuals is also found between cluster 60 (average linkage) and cluster 56 (complete linkage). Again, the male s6 cluster is split up in two sub clusters in the complete linkage method. Also here, the minute difference in the ranges for the mean CC is noticeable between both methods: the average linkage method starts at a mean CC of 0.67 going up to 1.0 whereas the complete linkage method starts at a

value of 0.69. This is again caused by the same fact, already mentioned above: that some individuals which were included in the analysis by the average linkage method had a CC value slightly below the given marginal value.

4.4. Females and calves

What is noticeable is that most of the clusters varying in size are composed of adult females and their calves (except the s1 cluster). This fact, and the fact that many of the smaller clusters also have this composition, points to a fission-fusion tendency among the females with their calves, or at least that the basis of these groups is close to a fission-fusion model. A good definition according to Conradt & Roper (2005) is that a fission-fusion society is a society in which groups of different sizes exist which "*form, break-up and reform at frequent intervals*". The alternative to this is a system in which little temporal changes in associations occur, at least regarding short periods of time (Whitehead 2008). The presence of a fission-fusion society is indicated by a fall over short periods of time in the so called (standardized) lagged association rate (Whitehead 2008). This association rate addresses temporal scales of a society, in contrast to methods like ordination, cluster analyses, network analyses, dominance hierarchy etc.. Thus, lagged association rates are a method for describing the temporal patterning within a dyadic or bigger relationship (Whitehead 2008). By fitting other models to those lagged association rates, structural aspects of a social organization can be uncovered as well as an estimation of the parameters of that structure. However, this has not been done for the present study and remains an additional point of focus for further analysis of the data.

It has shown that the mother-calf bond is very strong and forms the basis of social organization among females (Whitehead & Mann 2000). Looking at tables 4 and 5 in chapter 3 it is noticeable that almost half of all females which were sighted at least ten or more times are not associated for both analysis methods. For the analysis for all individuals sighted at least twice, the pattern is a bit different: for the average linkage method almost 40% of all females are organized in pairs as well as in clusters. For the analysis using the complete linkage method this value was shifted slightly with just above 40% of the females being organized in pairs and a little less than 40% of them being organized in clusters. The reason that for the higher sighting rate females in most cases are not found to be associated, could be that many calves were sighted less than those ten times. A calf born during the third year of the study at the end of the season where data was collected and just sighted occasionally during the fourth year, would render it difficult to reach a sighting rate of at least ten times. With the small sighting rate of at least two times during all four research years, most calves get a high chance to be included in the analysis, unless they are born in the last year of the research period.

All stable associations in pairs or clusters are mostly formed with other females and calves (occasionally subadults). This also matches the outcomes of Hartman *et al*. (2008). However, because sexing is difficult without seeing the genital area it can only be determined for individuals who have been seen in close contact with a calf that they are definitely females. The question remains how many of the adults of unknown sex are also females (either too young or too old to become pregnant or simply infertile).

Reasons for females to form groups when having calves are diverse. Diverse reasons are actually not just true for females, a point which will be returned to below. In general "*there is no automatic and universal benefit from group living but there are automatic and universal detriments*" (Alexander 1974). Those detriments can be for example an increased possibility for parasite transmission and competition for resources. Therefore, it can be said that "*group formation will be favored only when the benefits of being with others outweigh these costs*" (Connor 2000). Also, according to Connor (2000) the existing factors which favor group formation or no group formation may "*change during the course of development, seasonally, or moment by moment*". Individuals often show quick adaptations to those changes. Connor (2000) also states that predation pressure is logically highest in newborns, simply because they are small and easy prey for sharks and sometimes even bigger whales. In sperm whales it was found already that this predation pressure is the primary factor accounting for their social organization (e.g. Whitehead & Weilgart 2000, Alexander 1974, Norris & Dohl 1980). The bigger the group the more protection there is for the calves. Since the ocean lacks many possibilities to hide behind, the only option is to hide behind each other (Connor 2000). Also Wells (1991b, 1993) found that females raising their calves together in groups have a significantly higher probability of successfully bringing up their offspring than females not living in groups. Here, the so called dilution and encounter effects play the major role. Those effects mean that an individual in a group has a reduced attack rate when detected by a predator than a solitary animal which has also been sighted. Thus, the attack rate decreases with increasing group size (Triesman 1975, Turner & Pitcher 1986). However, this is only true for predators which can consume only one or a small number of individuals. Pitcher and Parrish (1993) state, interestingly, that the assumption that a predator would detect prey more easily if it is organized in groups is not true. Hence, the dilution effect depends on the encounter effect. Connor (2000) explains further that the best effect the encounter effect can offer, without the dilution effect also playing a role, is to make animals which are gathered in groups no more detectable than solitary ones. However, the ones in groups would just be as likely to be eaten once discovered. Also playing a role in the same context are confusion and oddity effects (the confusion effect reduces the capture rate per attack because the predator has bigger difficulties to track a single individual in a group; the oddity effect says that an individual is less vulnerable the more look-alikes are around it), the selfish herd effect (individuals can select a position in the group which leaves them less likely to be a target than in a position nearer to a predator) or predator detection and vigilance (the chance of detecting a predator before it detects the group).

Another good reason why Risso's dolphin females are organized in clusters can be observed directly in the field: they babysit for each other when the mothers are diving for squid. Thus, when leaving the calf at the surface, it remains under a certain protection with the other females still around. In a more scientific term this babysitting is called allomaternal care. This behavior is known in captivity and in the wild for (among others) bottlenose dolphins (Gurevich 1977, Leatherwood 1977, Allen 1977, Wells 1991a), killer whales (Haenel 1986), and, for the study species maybe most important for comparisons, sperm whales (Caldwell & Caldwell 1966, Best 1979). The presence of an adult obviously reduces the predation risk. But according to Gaskin (1982) having to leave the calves at the surface while hunting is not the

only reason for tight groups in deep diving species as the Risso's dolphin. Differences in feeding competition between odontocetes and mysticetes may also be important. It was found for female sperm whales that if their favored prey (the same as what Risso's dolphins feed on) is distributed in a temporarily and spatial way, less feeding competition is produced than with the prey of baleen whales (small krill; Whitehead & Weilgart 2000). Whether this is true for the Risso's dolphins in this study cannot be shown clearly because data of the squid distribution in the area is lacking. What is known about the squid is that it occurs rather close to the coast which is an extra advantage for groups of females and calves because they can also use the protection of the coast as protection against predators as well as against rough weather conditions. Another advantage for the females is that they do not have to dive as deep for the squid as they would need to do in offshore waters. For them this means a lower energy output for the same energy input.

4.5. Subadults

In almost ¾ of the analysis for the individuals sighted at least ten times the subadults are found not to be associated at all. For the analysis of all animals which were sighted at least twice subadults are still not found in any association in $^2/_3$ of all cases. This is true for both methods used. In the case of at least ten sightings the rest of the subadults is evenly distributed over pairs and clusters. For at least two sightings about ¼ of them is organized in pairs. However, neither of the associations just among subadults shows a CC above the marginal value of 0.5: the reason why in tables 6 to 9 in chapter 3 no clusters of only subadults can be found. This is also in accordance with the findings of Hartman *et al*. (2008) who state that subadults do not stay in association with their mothers but leave their natal pods and show much lower degrees of associations in general. This is further supported by Connor (2000) who found behavior like this in bottlenose dolphins. Here, both sexes in subadults leave their natal pods but stay in the same area. Connor (2000) called this geographical philopatry. He further states that especially most males continue to live in their mother's home range. Furthermore, Amano & Miyazaki (2004) suggest that females of similar reproductive condition form clusters, whereas subadults leave their natal pods. This could also be observed during fieldwork off the south coast of Pico. It remains in contrast to e.g. the matrilineal organization in killer whales but is similar to sperm whale behavior (Whitehead 2003).

In tables 6 to 9 in chapter 3 it can be seen that subadults often mingle in clusters of females and calves or in smaller clusters with adults of unknown sex. That is for the few cases in which they are found in bigger aggregations than two animals. Here it could be assumed that the clusters of females and calves might be their natal pods and they are perhaps just about to leave them. In the clusters with the adults of unknown sex it might be assumed that those adults are also of young age. This would fit again with the findings of Hartman *et al*. (2008) that young adults apparently form new pods. Since age determination in this study relies on the scarification pattern of the animal, unless exact age is known for just a few individuals, it can also be assumed that it is sometimes difficult to draw a strict line between an older subadult and a young adult. However, field observations support the named assumptions.

4.6. Males

Identification of males was based on the same features as in the study by Hartman *et al*. (2008) which were constant absence of calves, observed behavior (mating, chasing females), higher degree of scarification and more robust body build. In tables 6 to 9 in chapter 3 it is noticeable that many groups consist of adults of unknown sex. However, many of them (like the s13, s15, s17, s31 cluster) even have a higher mean CC than some of the well known male clusters like the s6 group. Furthermore, they occasionally show a higher degree of site fidelity. Since Hartman *et al*. (2008) state that the stability of male clusters increases with age, the conclusion is nearby that the above named clusters as well as comparable cases also can be counted to the adult male groups. Another example is the s19+s4 cluster which also occurs for both methods in both analyses. Six s4 individuals of the cluster are clearly identified as males. Since such a strong, permanent formation is just said to exist among males, it is suggestible that also the s19 individuals are males. Though, these conclusions could only be tested without any doubt by means of DNA sampling. Up to now this has just been done for about 86 individuals of the Risso's dolphin population off the south coast of Pico and results are yet to be published. Also in the present study male formations seem to be stronger than female formations. Females may adapt more to the circumstance if they need the protection of a group for a present calf or not. This is in accordance with the findings of Hartman *et al*. (2008). Connor *et al*. (1992, 2001) found also in bottlenose dolphins that stable, long-term associations occur. However, these groups only consist of a maximum of three males. This is not true for the findings in the present study. The size of male groups varies mostly between three to six individuals. Bigger clusters, like the s19+s4 group, are exceptions. Also the well known local males of the s1 and s6 groups for example range around five to six individuals. Thus, as already Hartman *et al*. (2008) concluded Risso's dolphin males seem to form strong, long-term alliances and cooperate within clusters. Cluster forming and cooperation among males, just like in females, has diverse costs and benefits. Perrin & Reilly (1984) suggest a multiple male breeding system for Risso's dolphins. This would indicate high competition among males over access to fertile females, meaning females are the most important resource for males (Wrangham 1980). What is striking in this context then is that, according to Connor *et al*. (2000), at least males in bottlenose dolphins apparently sometimes support attacks on rival alliances to help other alliances to obtain a female rather than obtaining that female for themselves. At first sight this does not make sense if the individuals were not benefitting in one way or the other from it. The reason Connor *et al*. (1992) give is that such behavior is either driven by reciprocal altruism or pseudo-reciprocity. In the first, individuals simply exchange altruistic acts, but in the latter a certain benefit is expected by that action. In the example referred to, of bottlenose dolphins, pseudo-reciprocity could be the case if the assisting alliance was dominant to the one which it assisted and thereby could mate with the female anyway without having to herd it themselves. However, no proof is found which supports this idea. During field observations off the south coast of Pico it could occasionally be observed that sometimes a male cluster stole a herded female away from another cluster whereas, on another occasion, with another male cluster herding a female they did not interfere or even merged. One possible explanation for this could be kinship relations. This

would also explain stronger bonds in some clusters and looser bonds in others or when different clusters merge together just temporarily (as observed during fieldwork: one example would be the rather frequent merging of s5 and s9). Although Connor *et al*. (2000) also give this as a possible explanation there is no proof for it yet in Risso's dolphins. However, letting a relative mate with a female will at least provide the chance of passing on the family genes than letting an unrelated male mate with it. Though, this hypothesis would need to be investigated by mean of DNA sampling.

Another reason also in males for group forming is predation. Although males form not as big clusters as females and their calves (at least not in this present study), still the above explained dilution and encounter effects care likely to play a role. During fieldwork also apparently old, strong male individuals could be observed with rather big bite marks and scars which could clearly be identified as rather recent shark bites. Therefore, adult individuals also do not lose this threat completely.

In order to be one of the dominant groups in an area to have easier access to females, food supply has to be assured. Thus, another reason to form stable, powerful clusters is the defense of prey and, therefore, habitat. According to Connor (2000) there are numbers of ways in which individuals can use access to food even when forming groups for other reasons. However, individuals are more or less expected to cooperate when resources require defending and can support more than one individual over a longer period of time. This again cannot be clearly said for the situation off the south coast of Pico because squid numbers are not known. High site fidelity which is shown in the analysis though indicates that there must be enough squid available to sustain several hundred Risso's dolphins, as well as other squid eaters as e.g. sperm whales. Field observations have shown that Risso's dolphins mostly use the night hours for feeding (Hartman 2011, Pereira 2008). Even the tight cluster formations spread out over larger areas when feeding, starting the dispersal in the late afternoon hours. It is known from sperm whales for example that they also spread out and line up over several miles when hunting for squid (Whitehead 1989, 2003, Whithead & Jaquet 1999). Doing this, individuals can benefit from searching a bigger area for prey than would be possible by hunting solitarily. Since it is also known that their preferred prey distributes evenly and widely over larger areas (Cockroft *et al*. 1993), this behavior clearly makes sense. Also the fact that they cannot dive for an unlimited time, searching an area with more animals provide greater foraging success. That Risso's dolphins defend their food resources off Pico Island was observed several times during fieldwork. In particular males were observed harassing pilot whales, sperm whales and, on one occasion, even false killer whales (Hartman *et al*. 2008).

Thus, group living in male Risso's dolphins might be an adaptation to optimize success in foraging as well as optimized access to fertile females with the added bonus of enjoying higher protection from predation. As has also been found by Connor *et al*. (2000) for bottlenose dolphins, male Risso's dolphin cluster pods can be recognized by their synchronous movement during swimming and diving. In bottlenose dolphins this synchrony in moving as well as a certain proximity and physical contact are an expression of affiliation (Connor *et al*. 2000).

4.7. Pod size

In the present study cluster size ranges from three to 17 individuals. This is slightly bigger than the findings of Hartman *et al*. (2008). That range really appears rather wide regarding optimal foraging and reproductive benefit. As already described above for males and females, there is a certain group tendency of squid-eating species for hunting simultaneously in the same area and often in bouts (in the case of the Risso's dolphins mainly during the night). However, the benefits of this are still uncertain although explained earlier by Whitehead in 2003. If it is true then group size is likely to increase in order to benefit from foraging success (also stated by Hartman *et al*. 2008).

Regarding reproductive benefits concerning group size one has to distinguish between males and females. As mentioned before, Connor *et al*. (1992, 2001) found that the optimal group size for male bottlenose dolphins seems to be three. For this size the balance of sharing fertile females with allianced group member apparently is best. In this study however, it showed that this apparently is not valid for Risso's dolphins. If the fact discovered by Connor *et al*. (1992, 2001) was true, then smaller male clusters would have higher benefits for reproductive success. This is not the case in the present study. For males it tends to be better in Risso's dolphins to form slightly bigger groups so as to be able to defend their habitat (females and food). Admittedly, it was also shown in bottlenose dolphins that just temporarily larger clusters form out of the small alliances in order to have better chances in the competition for fertile females (Connor *et al*. 1992, 2001).

As the case of the subadults shows, Risso's dolphins do not disperse far from their natal area. Therefore, as adults they still share the same area (accurate home range sizes are not known yet). Also in this respect it makes sense to form larger groups. Firstly, because it is easier to live in fewer larger groups than in more smaller groups and secondly because a larger group means more power in the competition over resources in general.

Regarding the females, Whitehead & Mann already stated in 2000 that their reproductive benefits are mainly related to the survival of their calves. Therefore, a bigger group has greater benefits because it accounts for better social support and protection (Hartman *et al*. 2008). Also foraging benefits present a reason to form bigger female groups because the individual can dive longer while the calf is taken care off in contrast to having to leave it alone at the surface and therefore taking a shorter dive. The conclusion Hartman *et al*. (2008) drew out of this is that "*female pod size will be positively influenced by both forces [foraging and reproduction], while male pod size will be a trade-off between foraging and reproductive benefits*". This is also valid in the present study.

During fieldwork it has often been observed that different clusters join together temporarily and split up after a while again. Preferences as to which group to merge with have not been investigated yet. However, observations indicate that there are indeed certain preferences. This will have to be investigated in further research and maybe also DNA sampling might give more insight in this. What is clear from observation is that when merged groups split up, they always split into the same smaller cluster pods again. Thus, the high dynamic of a real fission-fusion society cannot fully be found in this case. A potential explanation for the occasional merging with other clusters to form bigger groups could again be the protection of

the bigger group which has been observed before in e.g. offshore bottlenose dolphins (Connor *et al*. 2000, Norris & Dohl 1980).
Generally speaking it can be concluded that advantages and disadvantages of group forming are more or less true for all age and sex classes but just have a different emphasis.

4.8. General social structure

In the present study most individuals were found in no association at all. Rather high percentages ranging from 68% to 77% for the different methods and analyzed population sizes can be seen in tables 4 and 5 in chapter 3. This is followed by the next biggest group (with a range of 13% to 20%) being organized in pairs and fewest animals (range of 10% to 12%) in cluster pods. Composition of the pairs is mainly females and their calves. Such pairs are often found to be organized in bigger clusters for the above described possible reasons. The biggest fraction of individuals forming clusters however are males and the highest in not being associated at all are subadults. The composition of the bigger clusters is in most cases quite homogenous regarding sex and age class. Thus, also in this study the before found stratification based on age and sex classes in Risso's dolphins was detected. Bräger stated in 1999 that similar patterns in social structure and stability were already found in Hector's dolphins (*Cephalorynchus hectori*) which are similar sized as Risso's dolphins. Also for bottlenose dolphins a certain differentiation in range patterns and group forming according to sex differences was occasionally detected (Connor *et al*. 2000). In agreement with the findings from 2008 (Hartman *et al*.), the findings in the present study show basic structures of a fission-fusion society. That is shown in the fact that a big part of the analyzed individuals is not associated at all and females were mostly just associated when having calves. In addition, subadults seem to leave their natal pod to form new associations. But in contrast to real fission-fusion societies a rather high percentage of the adult individuals were organized in stable, long-term clusters with quite high CCs. Also the stratification along age and sex classes has not been documented yet for fission-fusion societies. The high degree of non-associated adults of unknown sex could be explained again by the fact that it cannot be determined clearly how old they really are. The looser formation might still be formed by slightly older animals than the subadults. However, it appears that stable formation are formed earliest in later subadulthood what also does not account for an organization as the matrilineal societies of for example killer whales or pilot whales. Whether the clusters are formed according to kinship relations is further investigated during recent DNA research not yet published (Hartman 2011, pers. comm.).
The social structure being in between the fission-fusion societies and matrilineal societies also fits with their body size being in between the species living in the named social societies. Hartman *et al*. (2008) strongly believe that evolution in preferred diet plays a role in this. They strongly suggest that stable formations provide considerable benefits in foraging and calf care as well as in reproduction. The fission-fusion model still forms the general basis of Risso's dolphin society but is more adjusted to the needs of a deep diving species in contrast to a fish eating species. This can be confirmed by the findings in the present study.

4.9. Differences in presence

For the analysis it is important to note that if some differences occur between the months throughout the whole research period it has to be kept in mind that there was no equal data set for all months. However, taking all data from the four research years together, Risso's dolphins were sighted during all months except for March where no data was gathered at all, most likely due to weather conditions. In the first research year very little data was gathered in comparison with the last research year for example. Corrections have been made for time spent on the sea in the calculations to make them comparable among all months, season and years but if there simply is no data at all the corrections do not help much. One reason for the different extensive data could be either another working method for the fieldwork at the beginning of the research or the influence of weather. Seasonal migration of the Risso's dolphins can be excluded because research has shown that there were already some resident individuals (mainly adult males and subadults) during the beginning of the research period (Hartman *et al*. 2009).

The picture that emerges according to monthly results accords also with the seasonal analysis. What is striking in the outcomes is, regardless of the non-existent data for some months during some years, that there are significantly more Risso's dolphins present during autumn and winter (from October till March) than during the rest of the year. This is in accordance with research off the west coast of the USA and Canada involving the same species (Forney & Barlow 1998, Baird & Stacey 1990). Off California Risso's dolphins' presence was also much higher during winter (around March) than during summer (July till November; Forney & Barlow 1998). A higher abundance in inshore waters during winter is also reported by Kasuya (1971). For bottlenose dolphins in the Gulf of Mexico however, it is reported the other way around. Especially from April to September they concentrate there in inshore areas (Connor *et al*. 2000). Shane *et al*. (1986) state that such seasonal habitat shifts are common in nearshore populations of bottlenose dolphins. This is thought to be dependent on changes in water temperature. However, the data needed to investigate this for the Risso's dolphin population off the south coast of Pico was not available for the present study. Generally speaking it might not account for the case of the Risso's dolphin population because for inshore bottlenose dolphins seasonal changes in range also could not be proved (Defran *et al*. 1999). Connor *et al*. (2000) state for resident killer whales that they also, in accordance with the bottlenose dolphins mentioned above, are rare during winter months in inshore areas. This is thought to be due to a decrease in their preferred prey (salmon species; *Oncorhynchus* spp.). Also, peaks in the presence of transient killer whales were found to coincide with peaks in pub weaning of harbor seals (*Phoca vitulina*; Baird & Dill 1995). However, this prey related reason can also in all likelihood be excluded for the Risso's dolphin population off the south coast of Pico, since their prey is abundant all year round and even providing enough numbers for the local sperm whale population. Nevertheless, in each case it remains interesting to relate the findings of Risso's dolphin's presence in the research area to water temperature, ocean currents or upwellings and prey abundance.

One influencing factor of the slight difference in seasonal abundance could be the fact that due to climatic effects, like for example El Niño, ranges expand and change (Leatherwood *et*

al. 1987). Such long-term fluctuations in geographical ranges (also due to environmental changes) were also discussed by Leatherwood *et al*. (1980), Sergeant (1982) and Connor *et al*. (2000). However, this does not fit with the reported resident population of about at least 170 individuals of Risso's dolphins off Pico (Hartman *et al*. 2009). Another, perhaps more likely than the afore mentioned, influencing factor could be the whale watching traffic taking place in the area from March till October. That this has a major influence on the Risso's dolphins has been proven by Visser *et al*. (2006) and Oudejans *et al*. (2007). What is distressing in this context is that the females especially could actually be expected to be more abundant in inshore areas during summer. The first calves are born around May/ June (Hartman 2011, pers. comm.) and that is exactly the time when most protection close to the coast would be needed as well as hunting in shallower waters and therewith having to leave the calf alone for less time could mean a substantial benefit for the females. Thus, the result that there are actually less animals around during this time of the year, shows that there must be a reason for the Risso's dolphins to avoid a potentially good living area which they occupy more in winter. The differences in presence between the four research years could also be due to more intense fieldwork in the latter years. However, according to Sergeant (1982) some populations of odontocetes simply differ in abundance over time. Whether Risso's dolphins off the south coast of Pico undergo certain periodical changes in their presence would need to be tested with a bigger data set. Since raw data is available from 2004 till 2011 this is likely to be investigated in further studies. Also here, a link to impacts of water temperature, currents or prey abundance would be interesting. Earlier studies in Washington and Oregon also indicated distinct interannual differences in seasonal changes as well as between years (Green *et al*. 1992, 1993). This could point to some periodic or circadian fluctuations in abundance, again requiring a bigger data set to be tested with.

4.10. Research methods and data processing

To be able to effectively manage and conserve wildlife populations a sound knowledge of biological questions about the species in question is a precondition (Speed *et al*. 2007, Auger-Méthé *et al*. 2010). This is often possible to be achieved by means of mark recapture studies. For at least 30 species of cetaceans this method has been used using natural markings for individual identification (Mann 2000). Also, Mann (2000) states that long-term studies provide the most detailed picture of cetacean social lives. It is essential to choose the 'right' mark types to decrease the eventuality of identification errors (Auger-Méthé *et al*. 2010). They should be recognizable over time, individually unique and have a rather high probability of being sighted and resighted (Würsing & Jefferson 1990, Karczmarski & Cockcroft 1998). Marks that change too much over time increase the possibility of identification errors a lot (Carlson *et al*. 1990, Dufault & Whitehead 1995). For most smaller cetaceans the shape of the trailing edge of the dorsal fin is the most significant feature (Würsing & Jefferson 1990). However, relying on just one identification feature may lead to misidentification of animals (Karczmarski & Cockcroft 1998). Hence, not just the trailing edge of the dorsal fin is an appropriate feature but also features like the general shape of the dorsal fin, shading of the fin, shading of the upper body, scrapes, scratches, wound marks on dorsal fin and upper body and

pigmentation patterns (Würsing & Jefferson 1990, Karczmarski & Cockcroft 1998). Thus, it is always better for more precise identification to use more than just one feature. This also has the advantage that even rather poor quality ID-photographs can be used for identification purposes (Karczmarski & Cockcroft 1998). For Risso's dolphins features like nicks on the dorsal fin, scars on the dorsal fin and upper body and the pigment pattern were used (Würsing & Jefferson 1990, Hartman *et al*. 2008). Since the scarification in Risso's dolphins can vary a lot over time, taking more than one feature makes sense in this species. Auger-Méthé *et al*. (2010) state that varying mark types should at least be suitable for use in studies spanning one field season. Since in the present study a more or less continuous follow of the animals is given, it can be assumed in this case that misidentifications are minor. However, there were a few individuals in the data for which neither sex nor age was identified (< 20 individuals). These have been left out of the analysis. Thus, using photo-identification as the basis of a study like the present one seems very well suited for the question.

In the present study the program R was used for analysis of social structure instead of the program Socprog (Whitehead 2009). Hierarchical clustering is done to assign a certain set of object or individuals into groups. This is done by both programs. While in the Socprog program the average linkage method is set as a default, in the present study the complete linkage method for the hierarchical clustering was used in addition. This has been done for two reasons. First of all, the complete linkage method was found to be 'more strict' in its definition (see definition in chapter 2) in assigning association. Secondly, since the aim of this study was also to find possible differences in the outcomes to Hartman *et al*. (2008) by means of alterations of methods, this addition of the complete linkage methods makes sense. Furthermore, a possible trend towards a fission-fusion society wanted to be investigated by altering the methods. However, a clustering coefficient is calculated by the Socprog Program as well as by R. A clustering coefficient is a measure of the degree to which associations of a certain animal are themselves associated in a binary network (Whitehead 2009). The Socprog program works with 'similarities' in finding out this degree while R works with 'distances'. However, by simply inversing the 'distances' from the analysis in R, the results become comparable to the 'similarities' from Socprog. Therefore, the use of the different method for analysis should not be seen as a decreasing point for the comparability of the results. Also the rather high conformities in the dendrograms of both studies, as well as the clusters found with both methods account for this.

In the study of Hartman *et al*. (2008) permutation tests were conducted in order to test for nonrandomness of the results. These tests are investigating whether associations are really formed because of preferences of the individuals being with others or just randomly. This has not been done in the present study. However, the results are so much in accordance with the findings of Hartman *et al*. (2008) that it was assumed that also in the present study nonrandomness of the results can be assumed.

The reason for taking such a low sighting rate of just twice sightings (thus just 1 resighting) is because according to several studies lowest sighting rates started around that value not only in

cetacean studies (e.g. Slooten *et al*. 1993, Whitehead *et al*. 1991, Underwood 1981, Myers 1983, Penzhorn 1984, Metcalf 1986, Weinrich 1991). For the analysis of all animals with the very low sighting rate, there were bigger groups being analyzed since fewer individuals were left out. Hence, group size for these analyses was in general bigger than for the analysis with animals which have at least been sighted ten times. Bigger groups mean that more dynamic within and also in between the groups becomes possible. Thus, the outcome that the Risso's dolphin society shows a tendency towards a fission-fusion society in the main features becomes quite logical with bigger, more dynamic groups being analyzed. Consequently, analysis with the at least ten times sighted animals shows a little less the main characteristics of a fission-fusion society. Groups for this analysis were smaller and thus a bit less dynamic.

There were a few things in the results of both analyzing methods where leaving out certain individuals for analysis was considered. For the analysis of at least two sightings the mean sighting rate often was just twice. Meaning, these animals in that particular cluster have really just been sighted twice within the whole 4 research years. The question is whether they were sighted the first time right at the beginning of the research period and the second time around the end or whether both sightings were very close together. It becomes difficult to conclude then, even when taking more years into account, whether these animals might show up in the area more often, forming a more stable part of the population off the south coast of Pico or whether they just pass by the area. When they were, for example, just sighted twice with a very short period of time in between each sighting right at the beginning of the study, there might be indications that those individuals do not form a real part or do not play a bigger role in the Risso's dolphin society in the study area. However, since the objective of this study was to also take all animals into account for analysis with such a low sighting rate, they were left in the data set for the analyses. Many of those occasions were actually females with their calves. Here, a lower mean sighting rate might make more sense than in other cases because when the calf is born towards the end of the study period it would increase the likelihood of this pair or small cluster of females with newly born calves not being sighted more often. However, the decision was to leave all groups and animals conforming to the set objectives in the analysis so as to not shift the results.
A similar 'conflict' regarding interpretation of the results arises when seeing the mean CC in relation to the mean sighting rate. In some occasions there is a rather high mean CC but a very low mean sighting rate. Thus, a cluster where all animals have just been sighted exactly twice all together at the same time will logically have high mean CC since they show strong associations for the two times being sighted. This has to be kept in mind when reading the results.

A general problem in the present study concerned the data processing where sometimes there were discrepancies found among two data sheets which should basically contain the same information but which were overworked or adjusted by different people throughout the years. This resulted for example in the problem of some discrepancies between sighting rates for individuals in between two or three different sheets. It was decided to always take the most likely data and the ones which could be found in more than one sheet. It was also noticed

shortly after ending the analysis that very few animals were still analyzed twice due to writing differences like blank spaces or underscores in the names in the original data sheets for example. With the intention of avoiding this, functions in the raw data in the excel sheets were used to take out 'double' individuals. However, at least one individual was still present twice in the dendrograms at the end of this study. Though, it can be assumed, since the percentage of 'double' animals is so minor, that it did not change the outcomes of the analysis.

5. Conclusion

This study fully supports the findings of Hartman *et al*. from 2008. The enlarged data set used for the present study did not alter the results. Risso's dolphin society seems to have a complex social structure with a strong stratification along sex and age classes. Either very strong, stable, long-term groups are formed or dyadic associations or no associations at all, depending on which sex and age class individuals belong to. Most stable associations were still found in males and the loosest in subadults. The mean group size was a little lower than in the results of 2008 and largest group size was higher. Driving forces for forming clusters differed between males and females. In the case of females, social support for calf care seems to be the predominant driving factor, while for males the main reason to form groups was access to fertile females. Subadults are 'trying' to form clusters after having left their natal pod. However, their associations are not very stable or of long-term duration. Logically, all costs and benefits of cluster forming will always be balanced in each species according to evolutionary adaptations and needs. However, the expected hypotheses are met in these respects.

The use of two different linkage methods altered the results to a minor degree regarding the outcomes about the social structure of the study species. However, the use of a lower sighting rate changed the outcomes slightly. More clusters were defined in general and for the lower sighting rate a more dynamic structure could be found showing a tendency towards a more fission-fusion society. These findings are thought to support the theory that the basis of Risso's dolphin society is tending towards a fission-fusion model (also see the dynamics of subadults) but comes out into the more complex, stratified society mentioned above because of the different needs of the sex and age classes. However, a big difference in association rates or site fidelity could not be found when handling the lower sighting rate. The only result in this direction was when animals were included which have just been sighted twice throughout the whole research period. Plausibly, for clusters consisting of them, site fidelity was really low. Also here, the before set hypotheses are met.

As expected, significant differences in presence were found for months, seasons and years. The differences mainly lay between spring/summer and autumn/winter months with more abundance during the latter. A rather big influencing factor is thought to be the intensive whale watching in the study area during the former. Influences like differing prey abundance or possibly changing water temperatures could not be investigated due to a lack of access to

such data. The different intensity of data collection between months and years was corrected for by taking the hours on sea into account and just calculating with the average number of individuals per hour at sea for all the analysis. The hypothesized differences between months, seasons and years were found although the findings were put independent of the time spent on sea.

An interesting development which remains to be investigated with reference to all findings is a possible relation to environmental influencing factors like for example changes in prey abundance, changes in nutrient content of the water and changes in water temperature.

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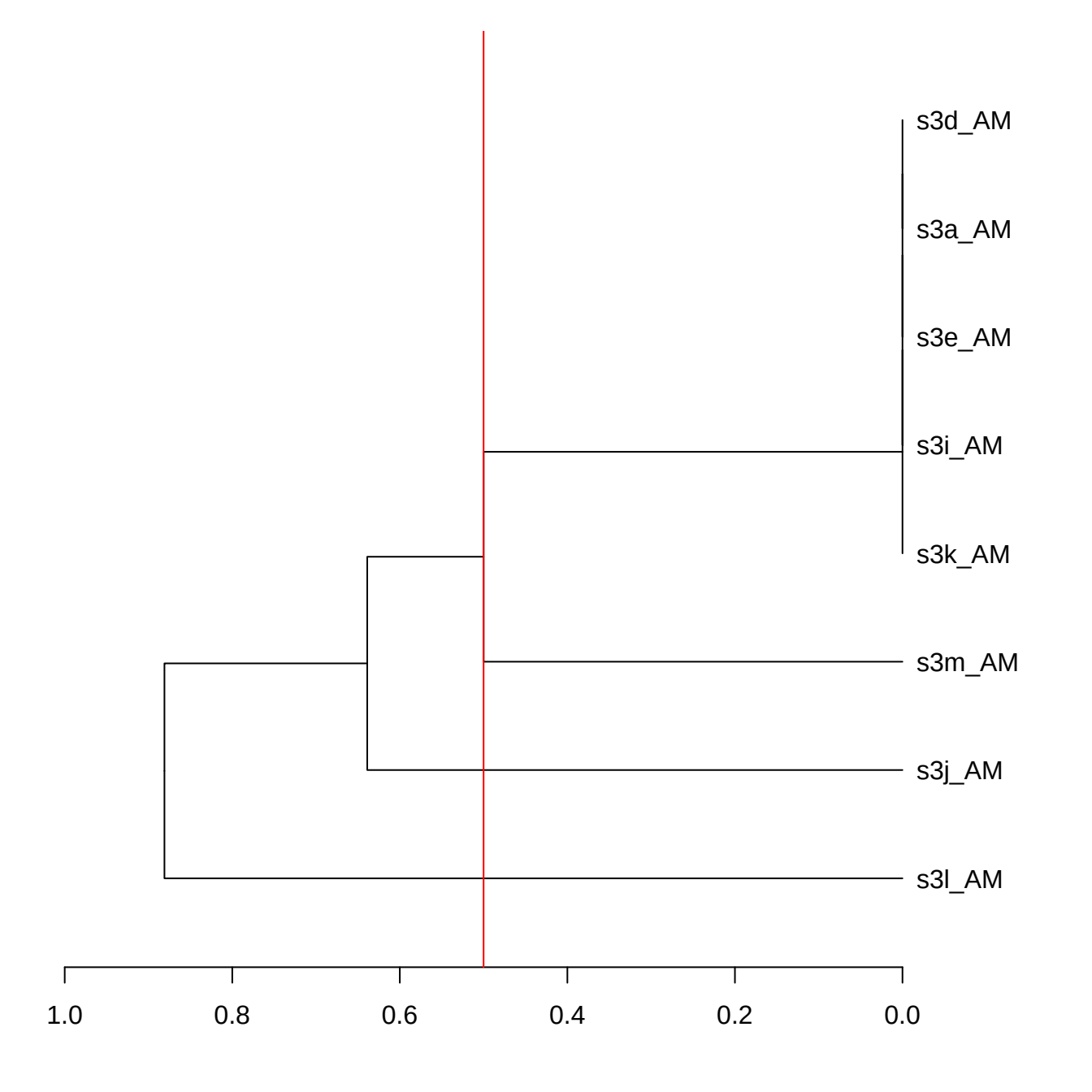
Appendices

Appendix I

Dendrogram for all individuals sighted ≥ 2 times

Average Linkage Method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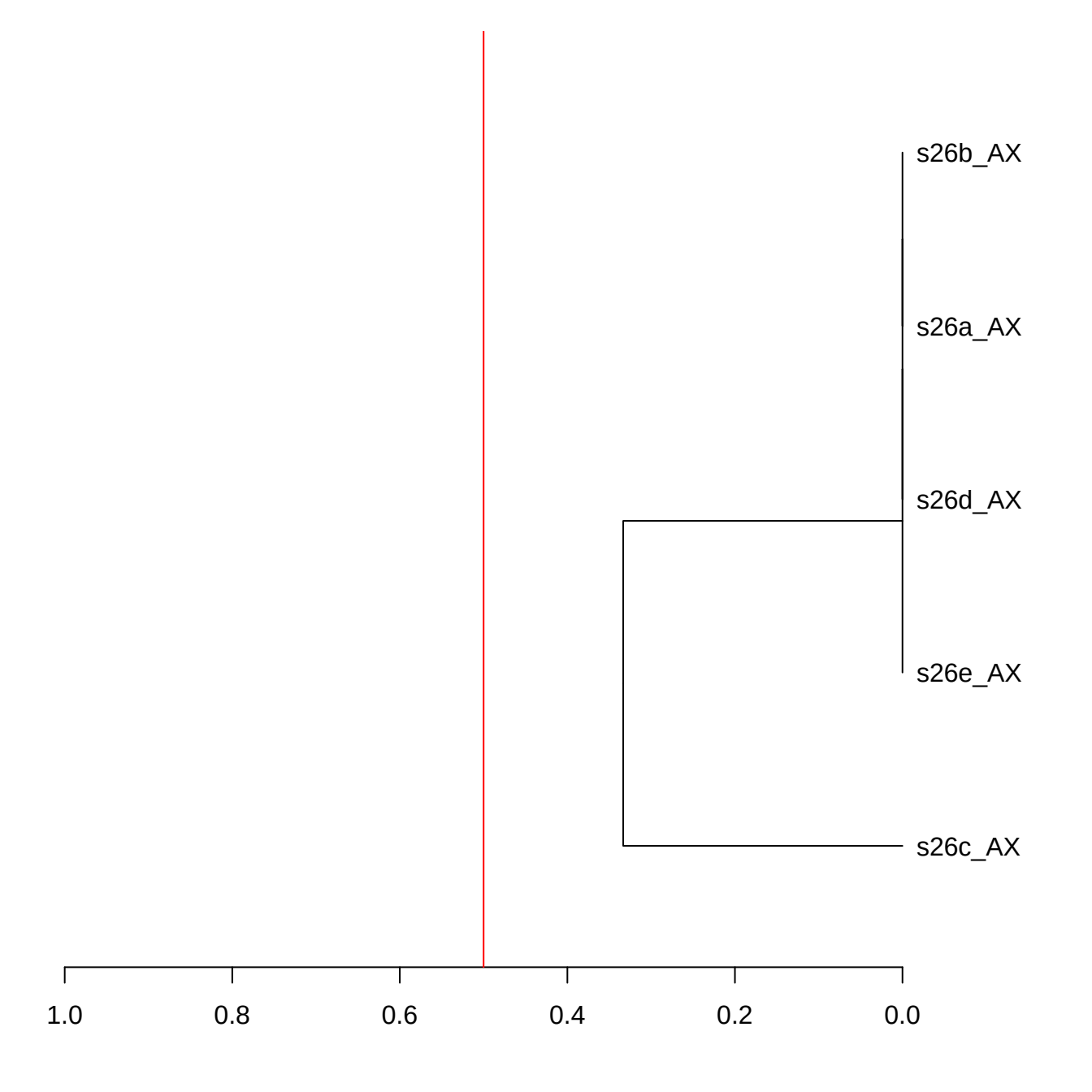
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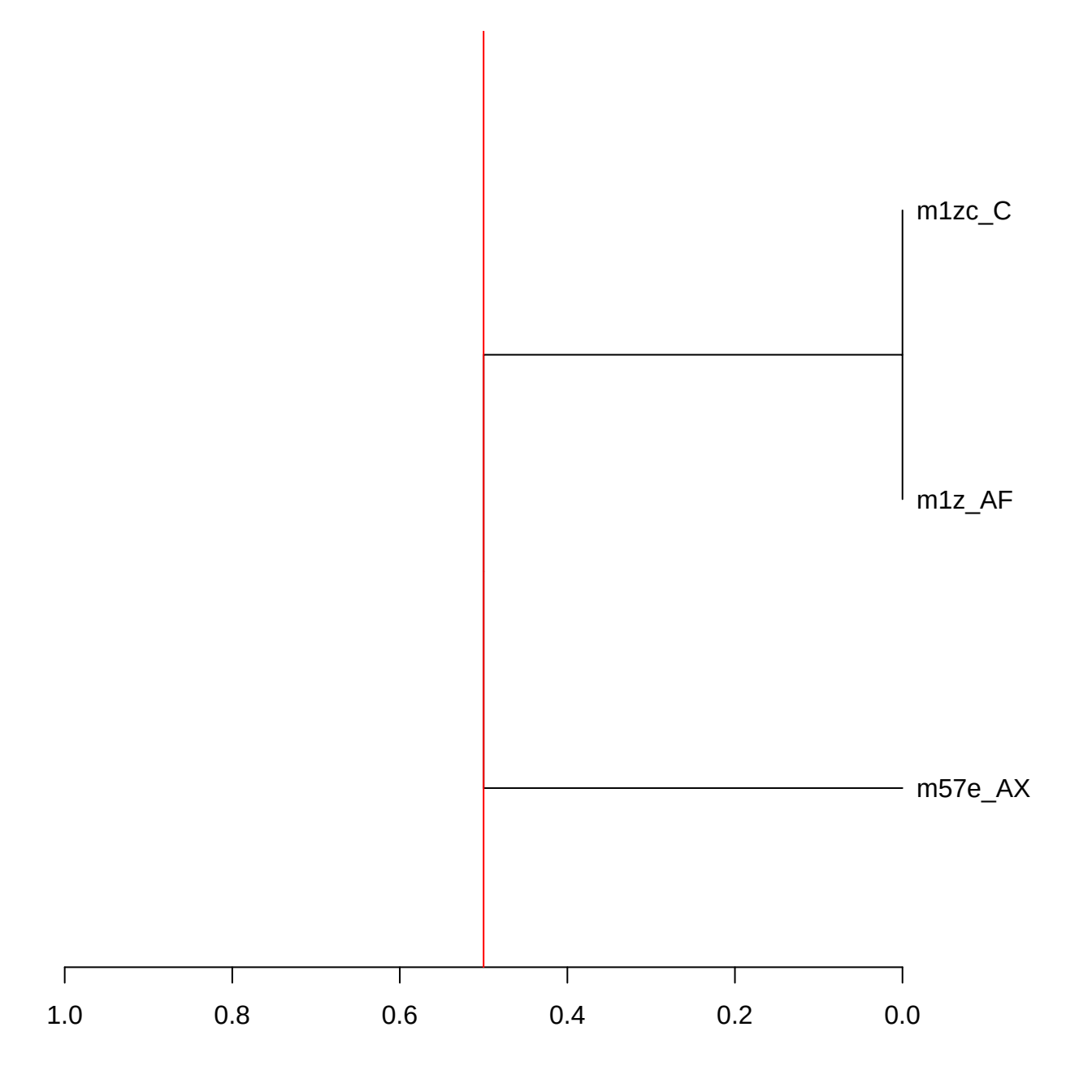
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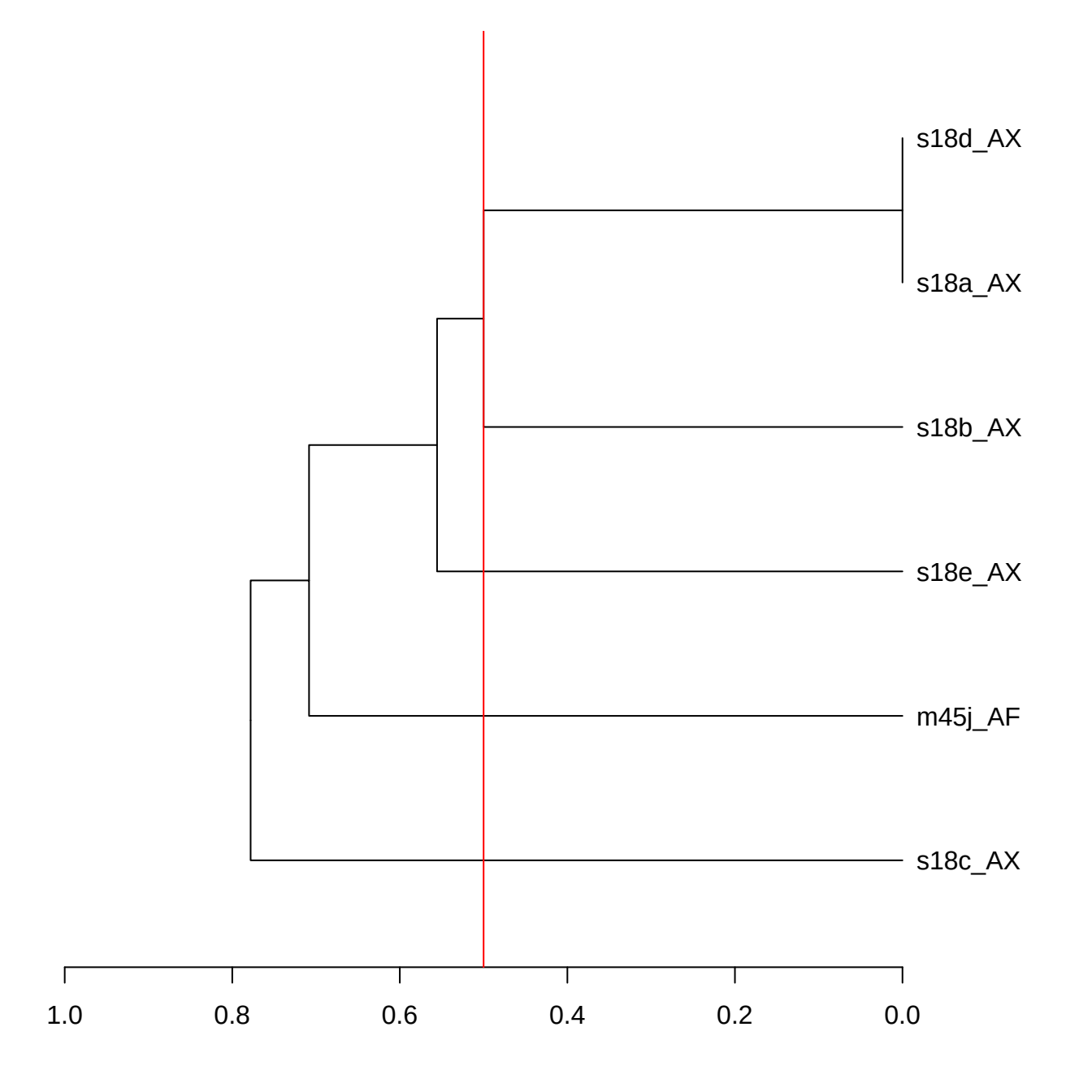
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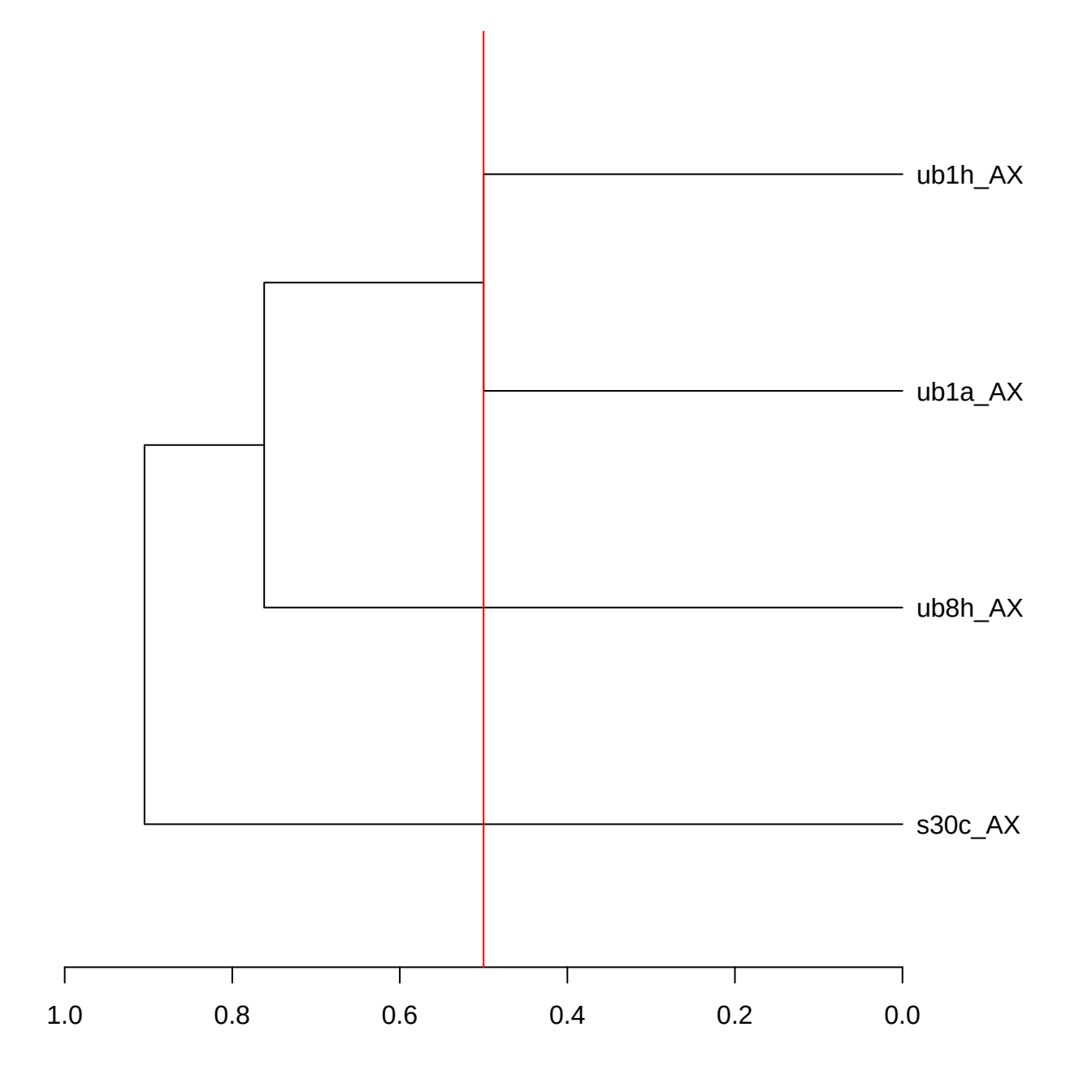
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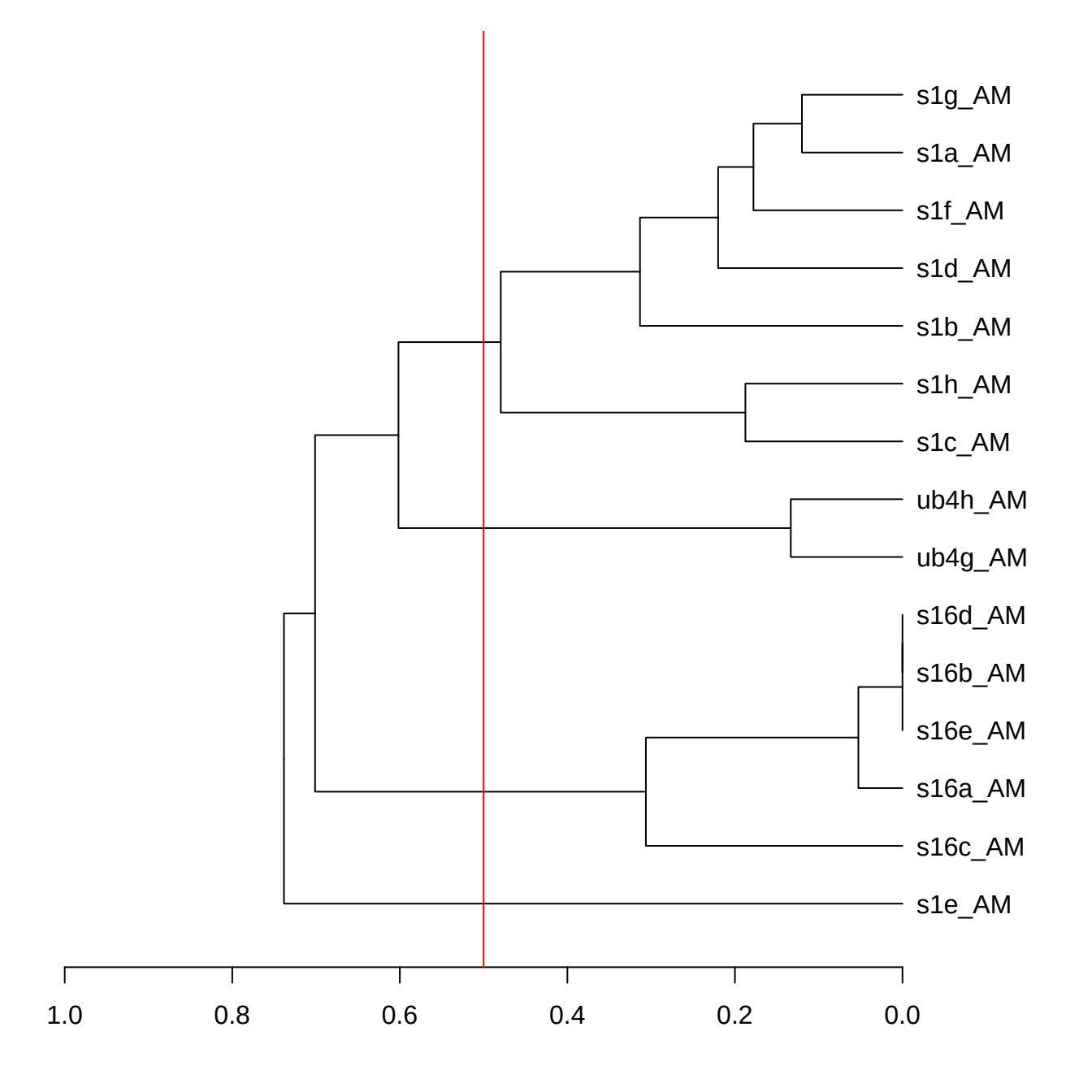
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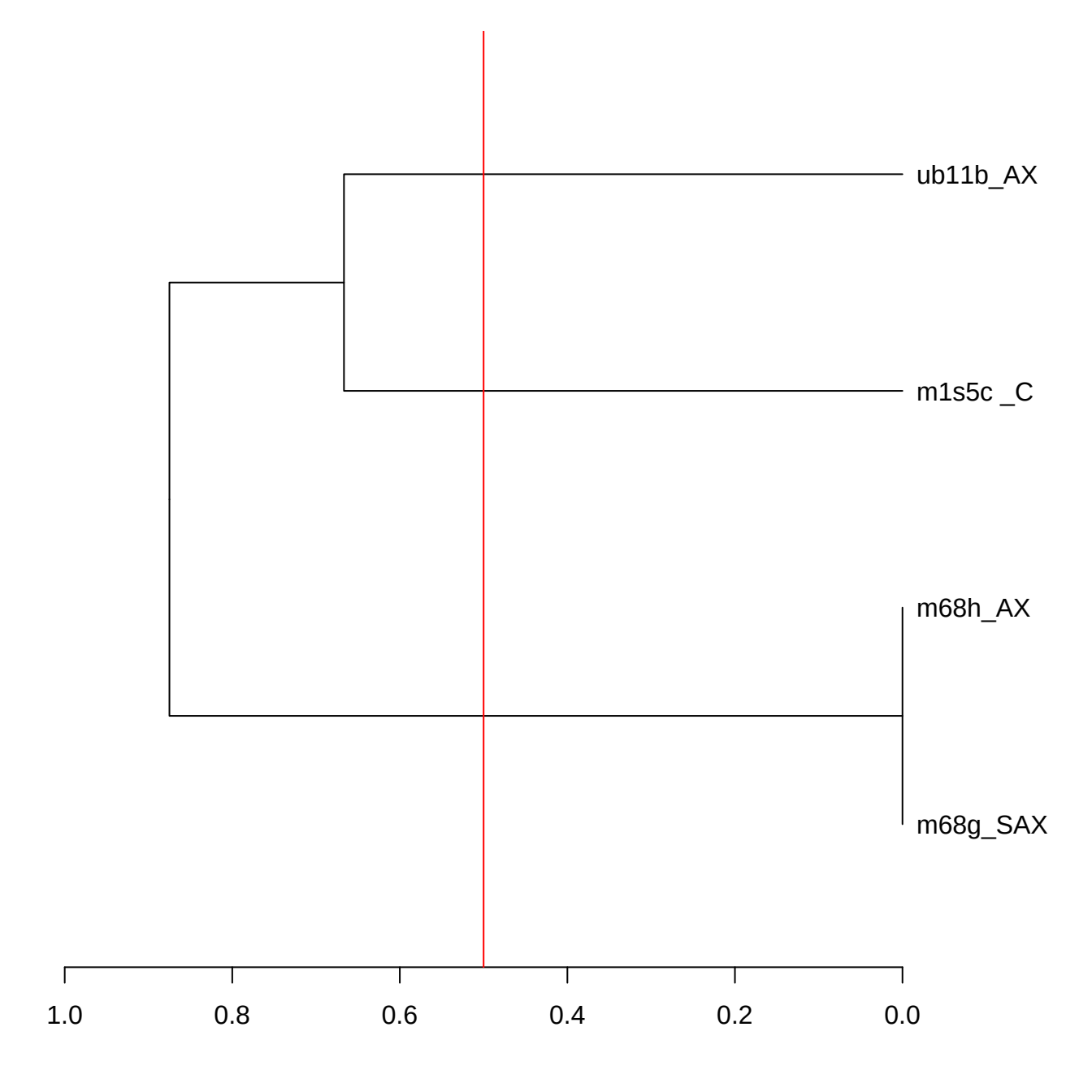
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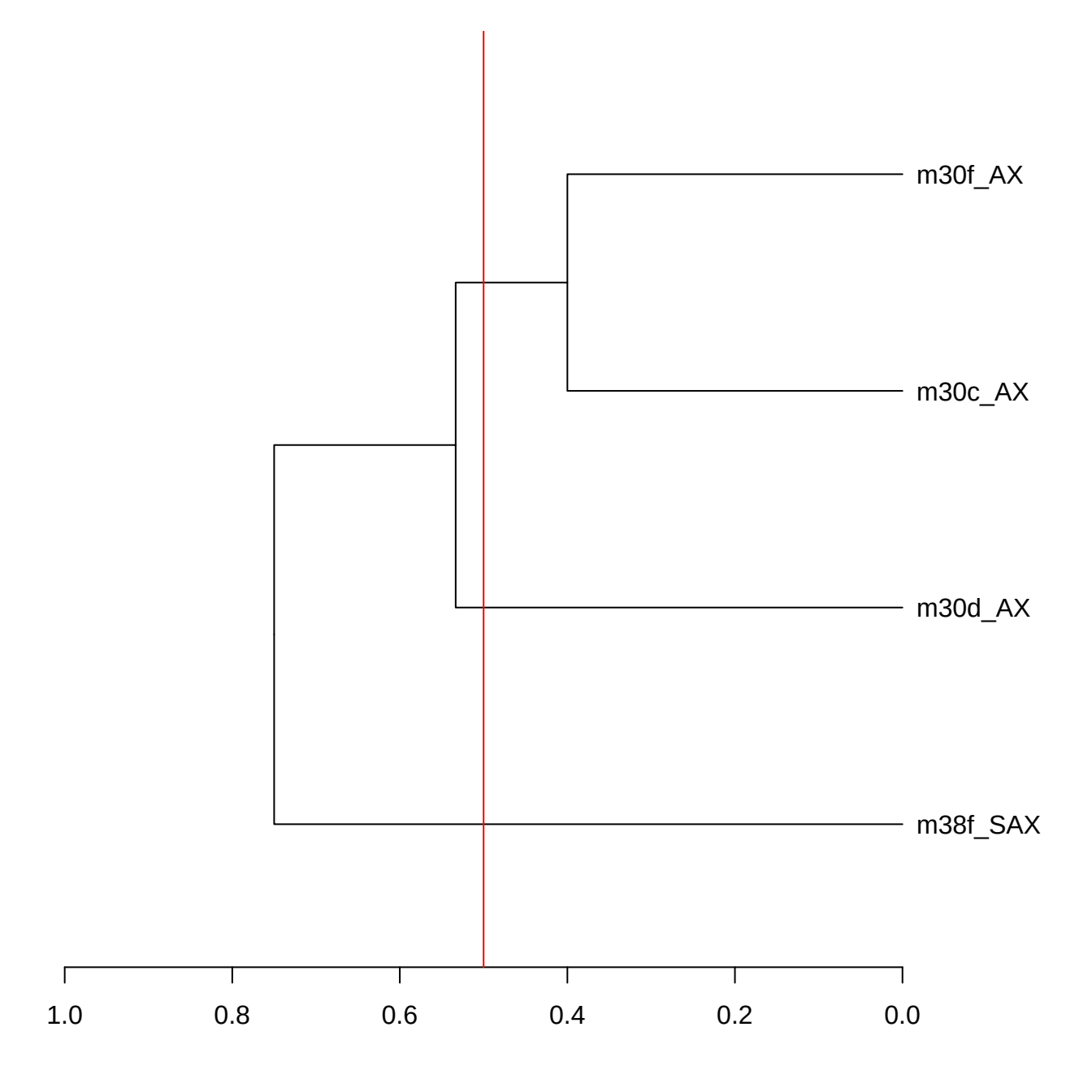
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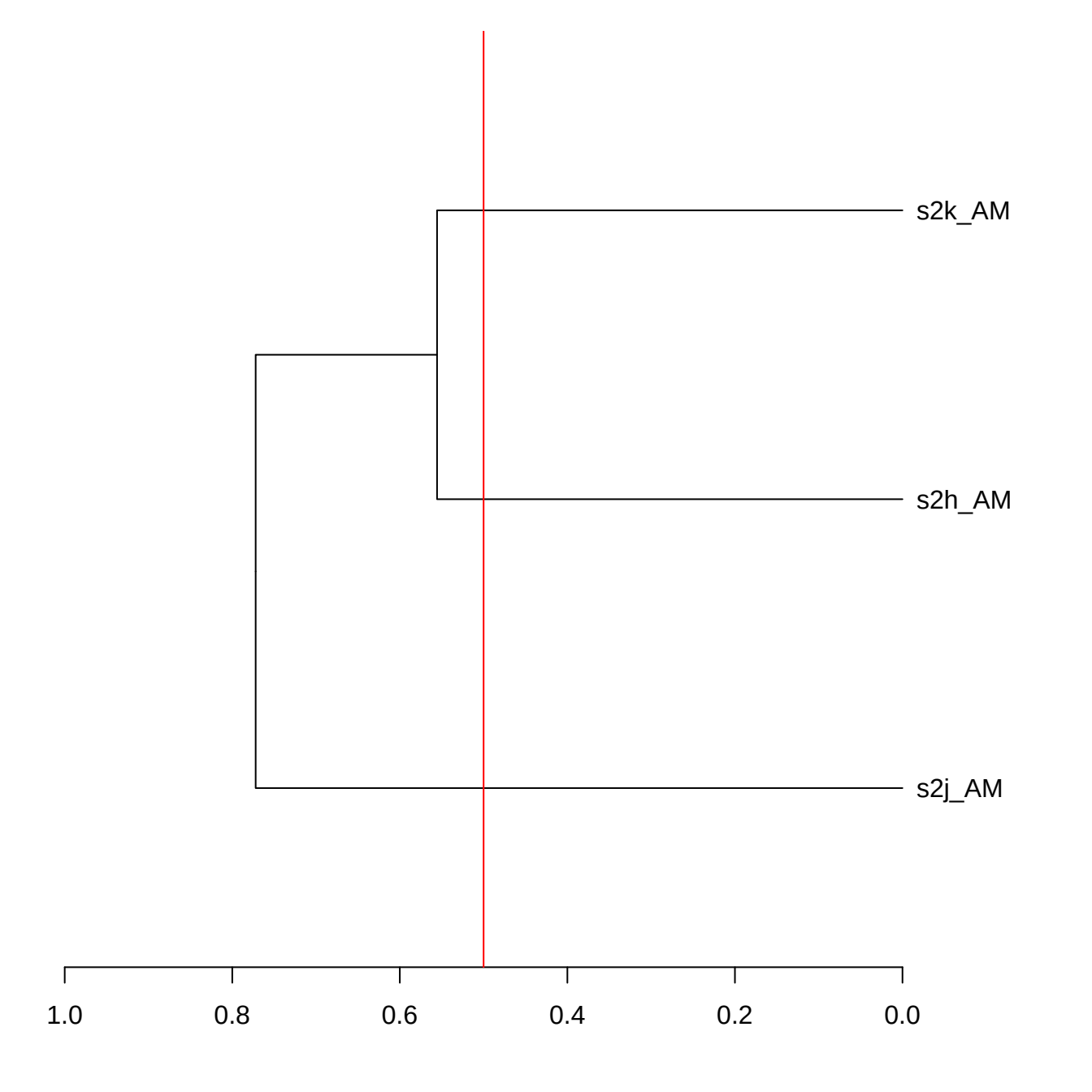
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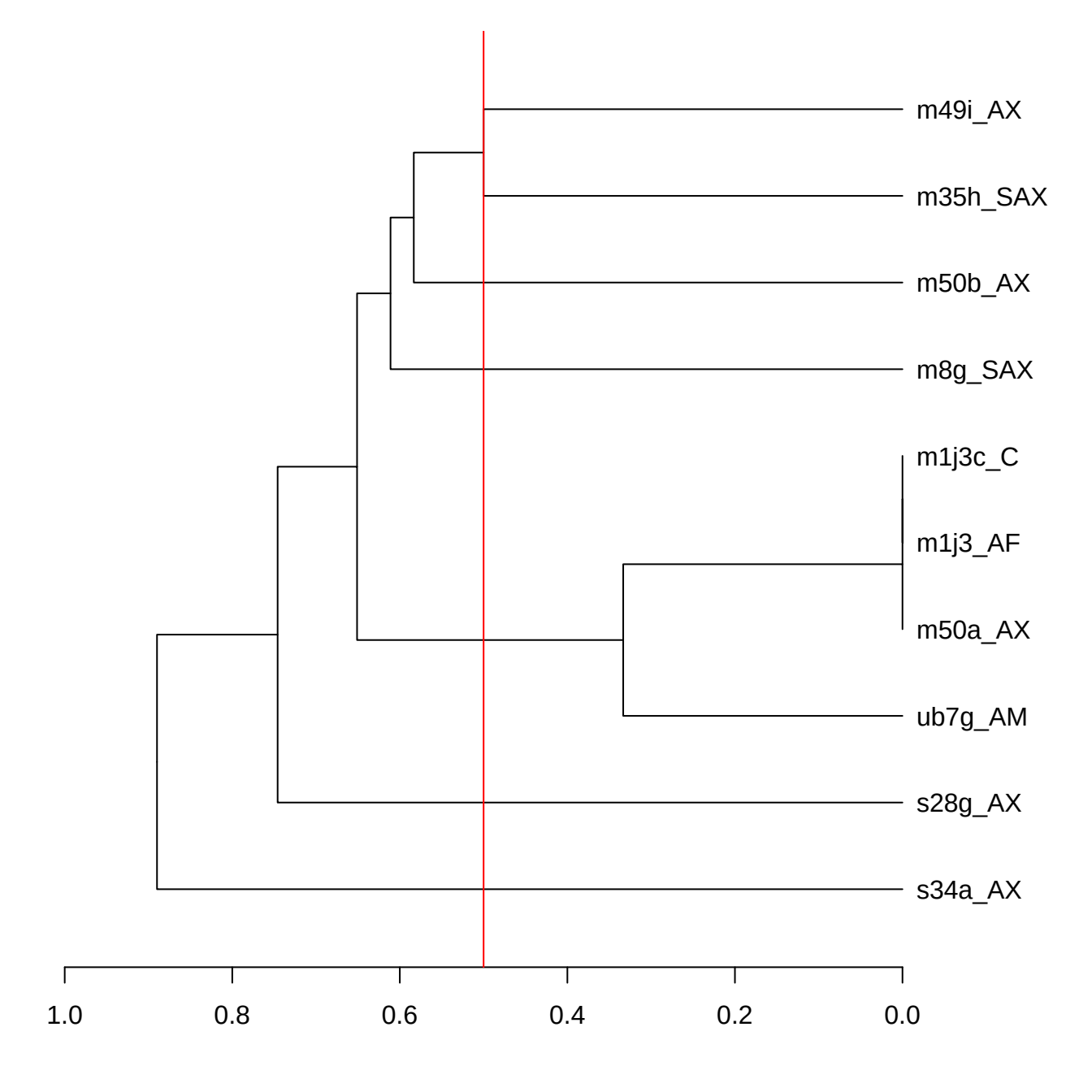
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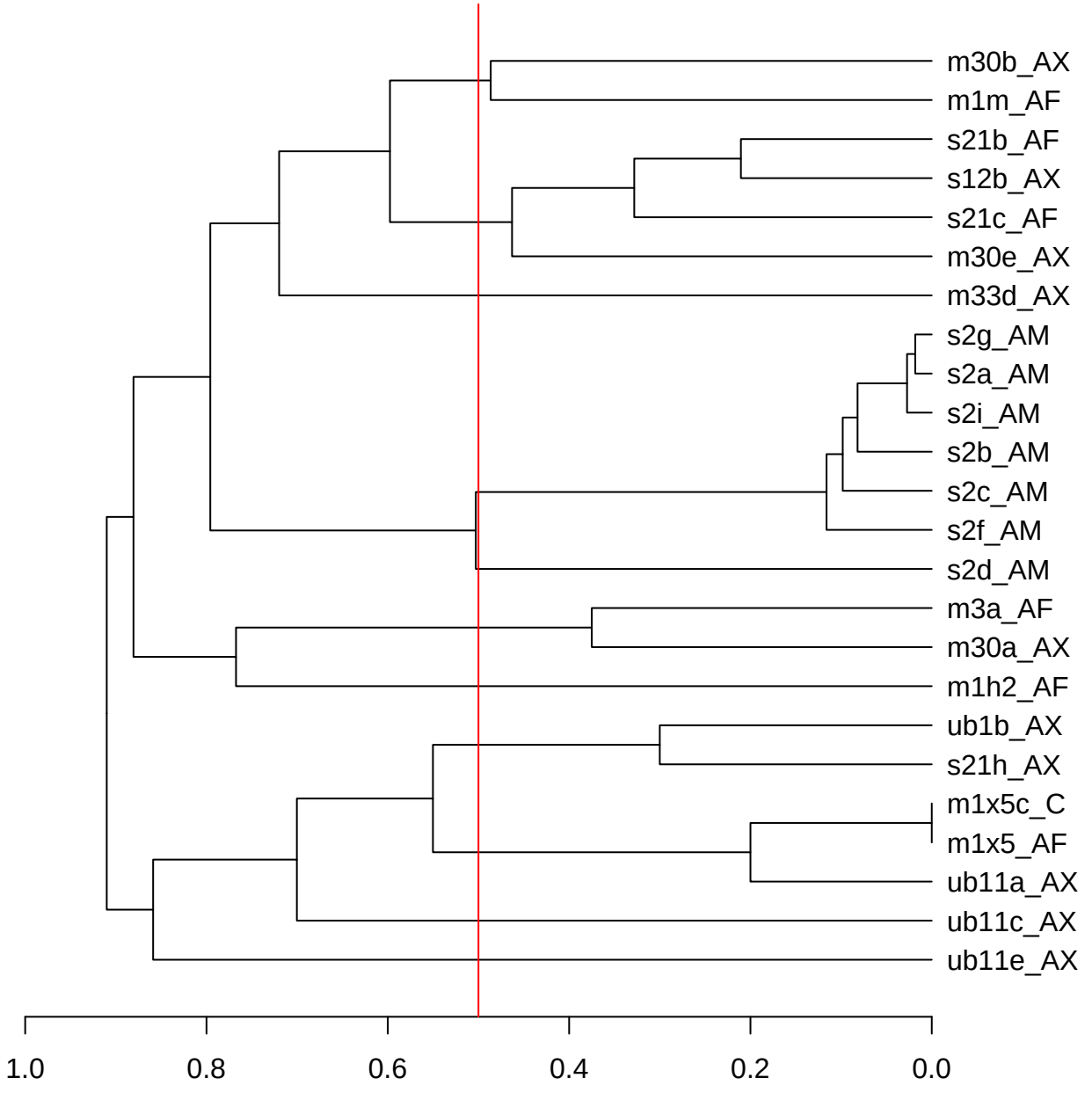
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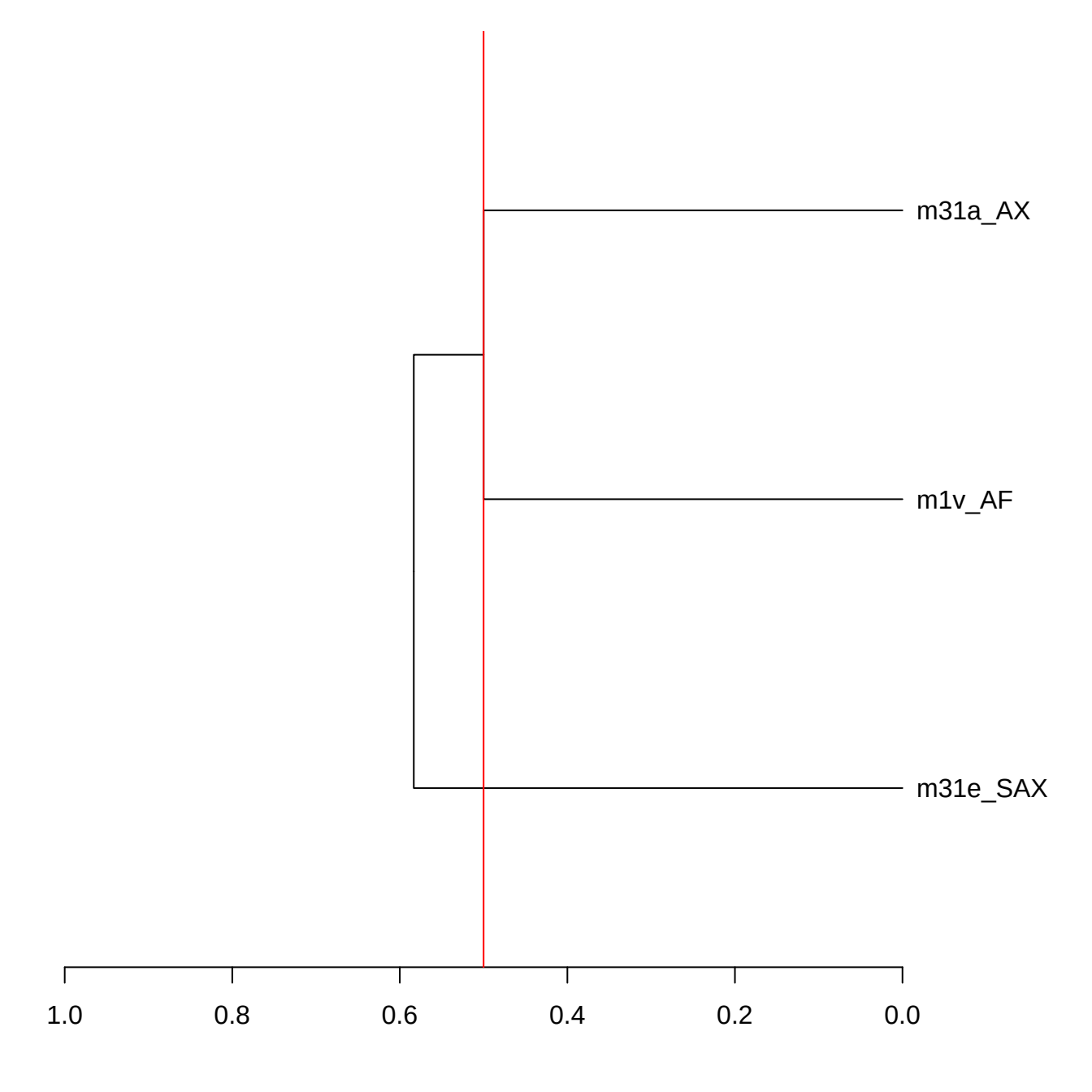
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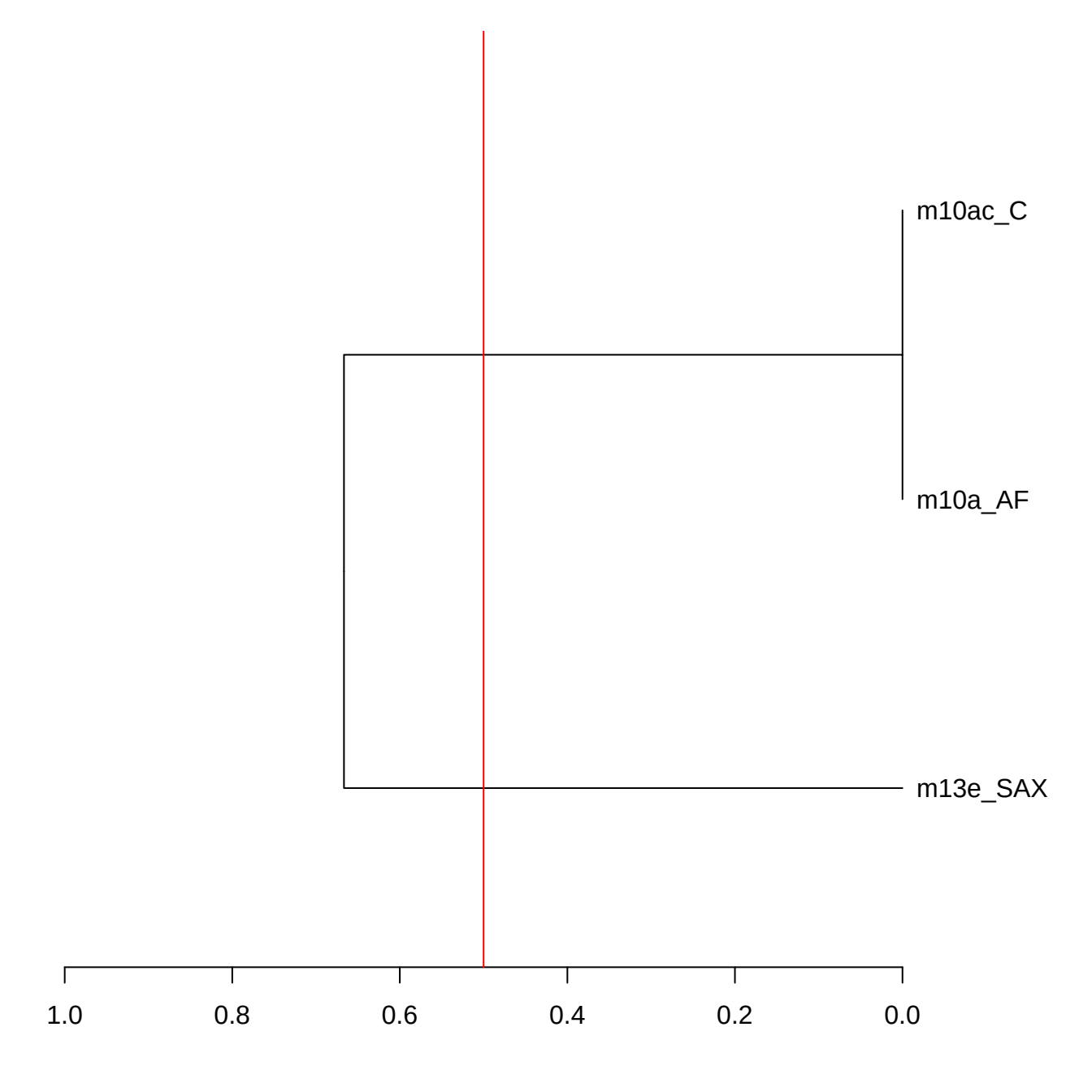
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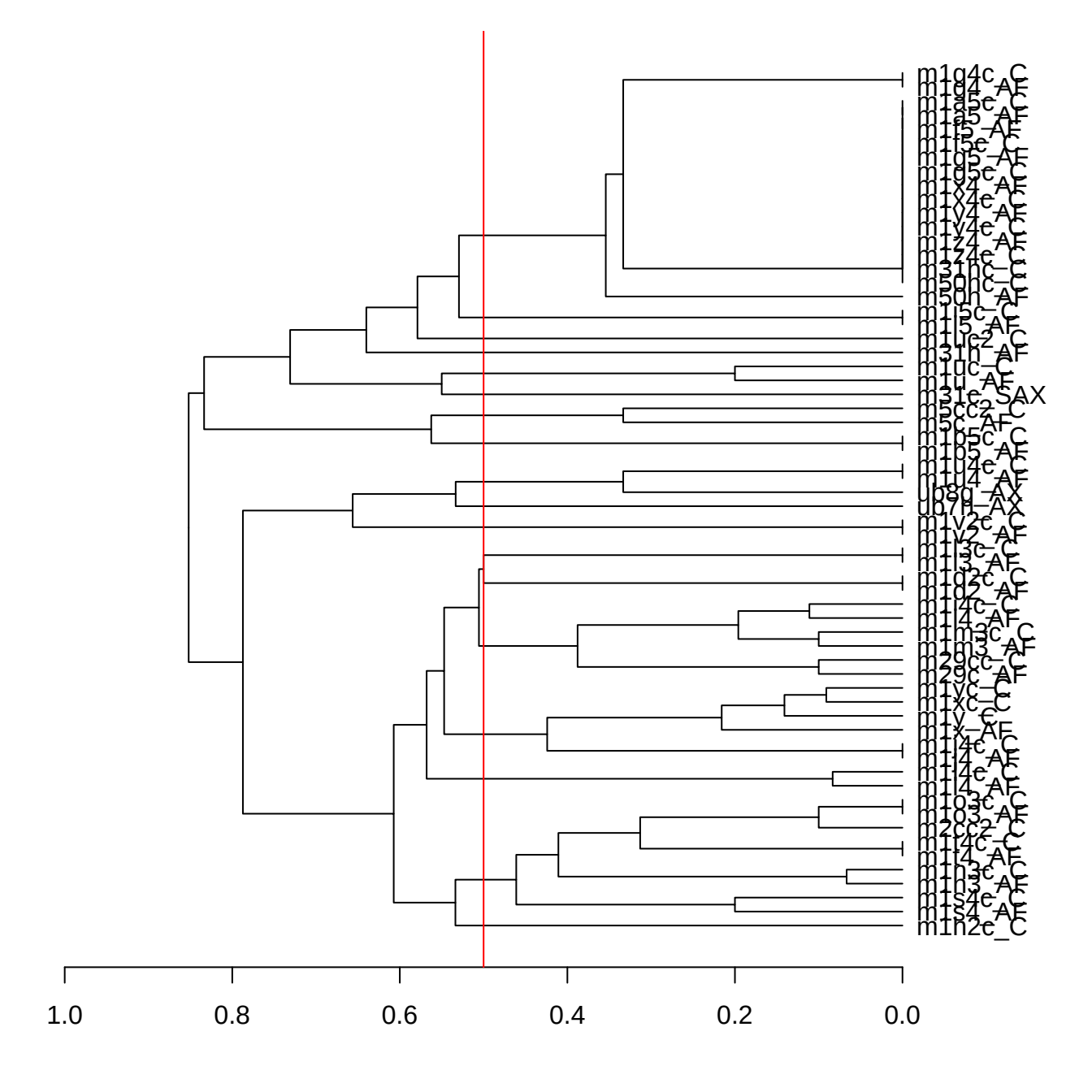
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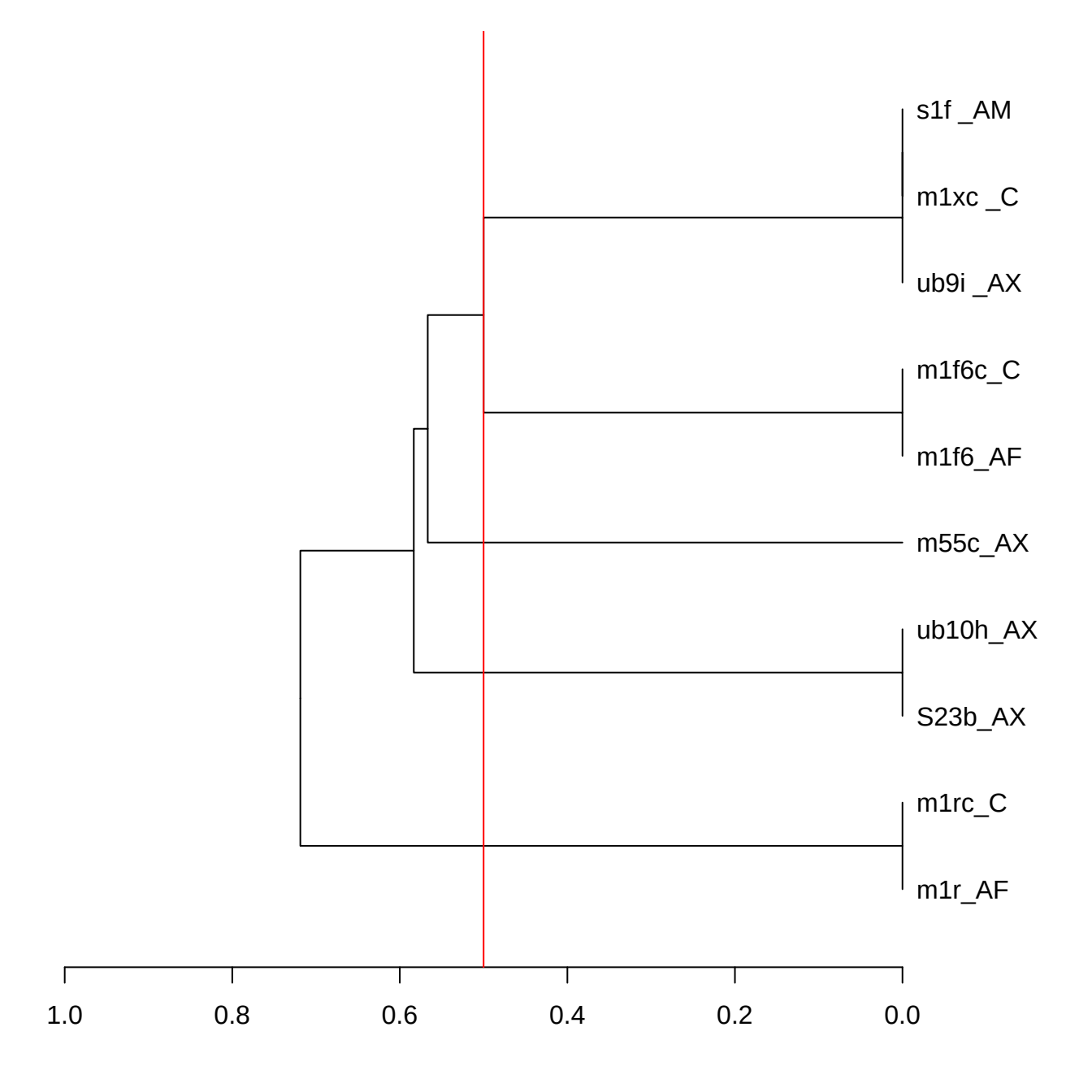
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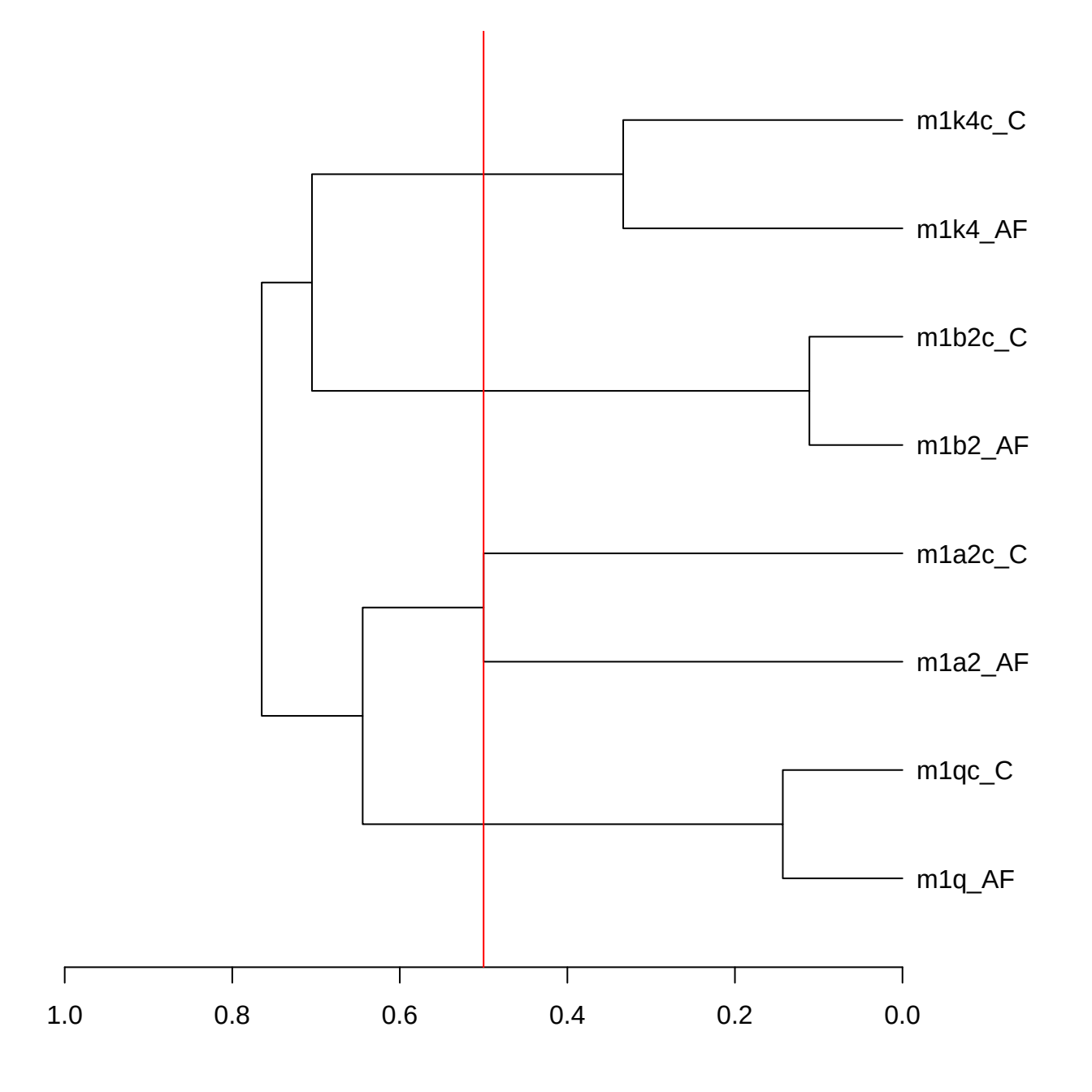
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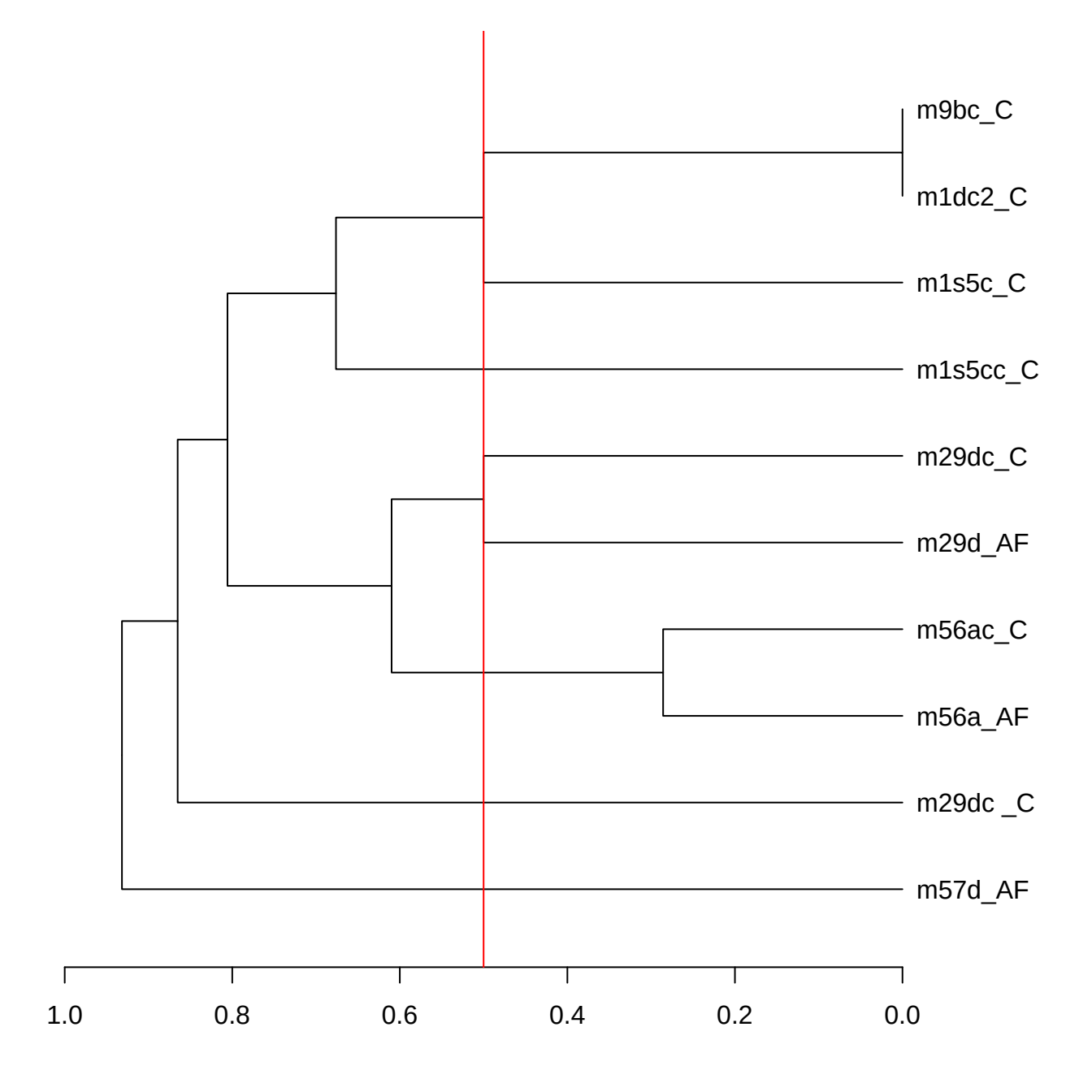
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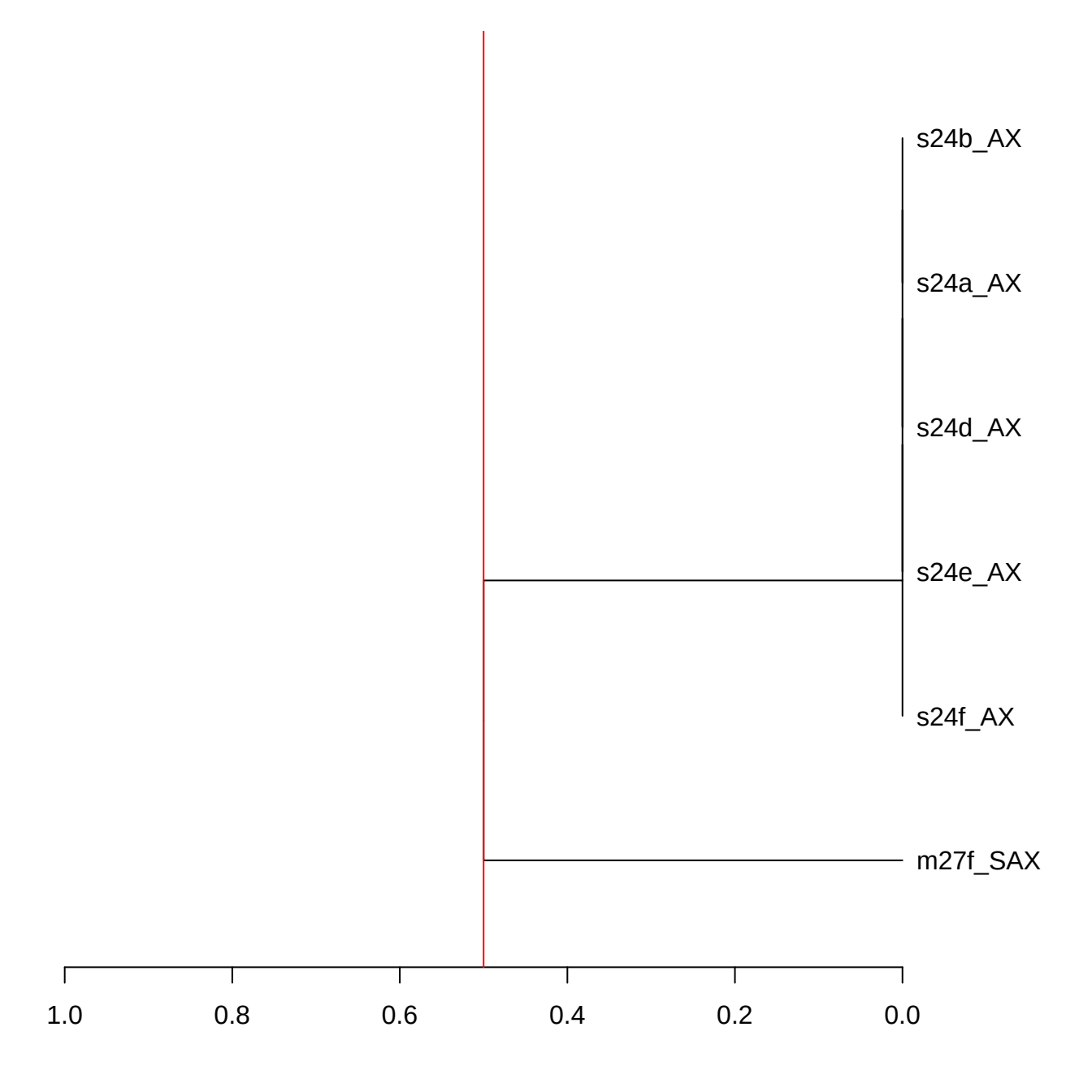
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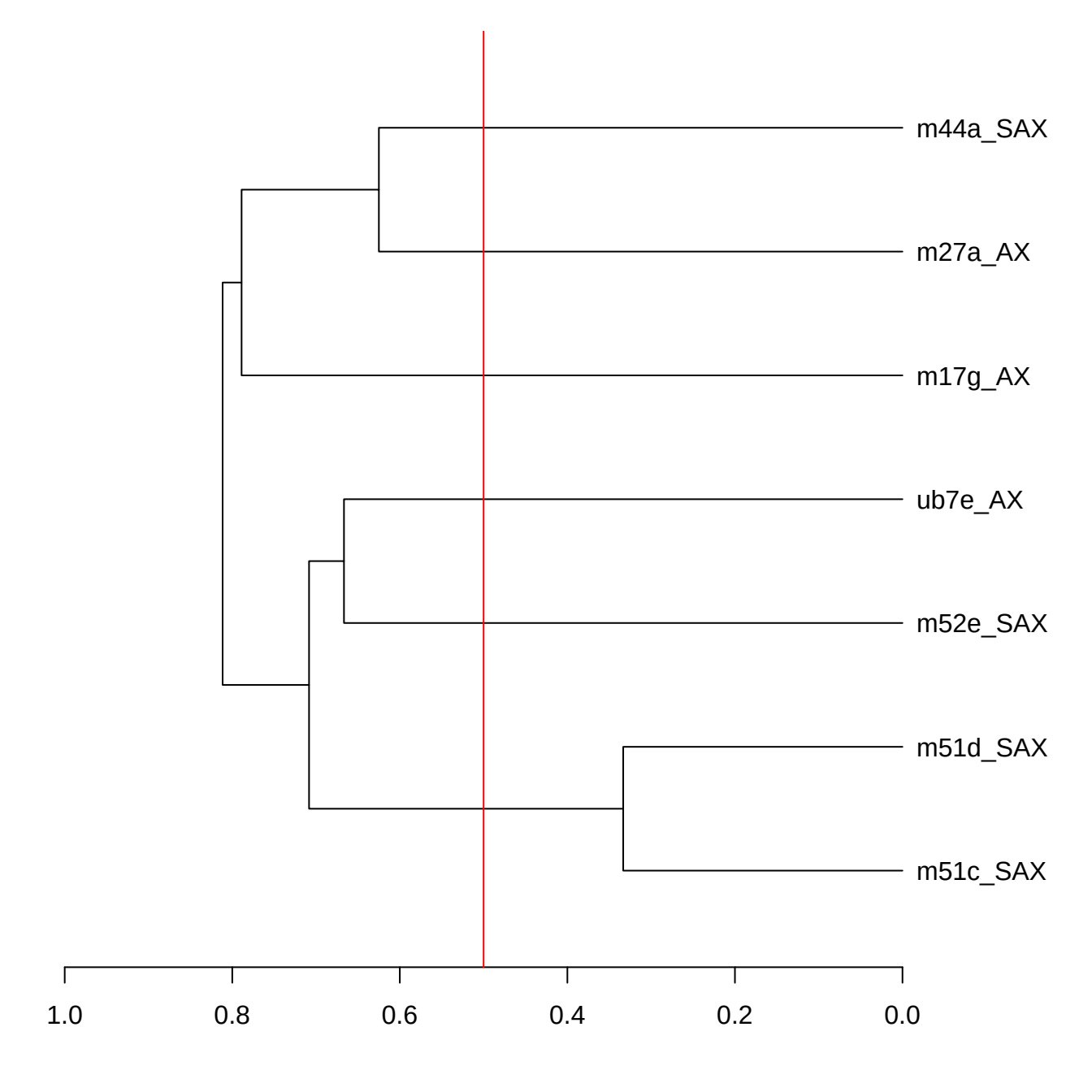
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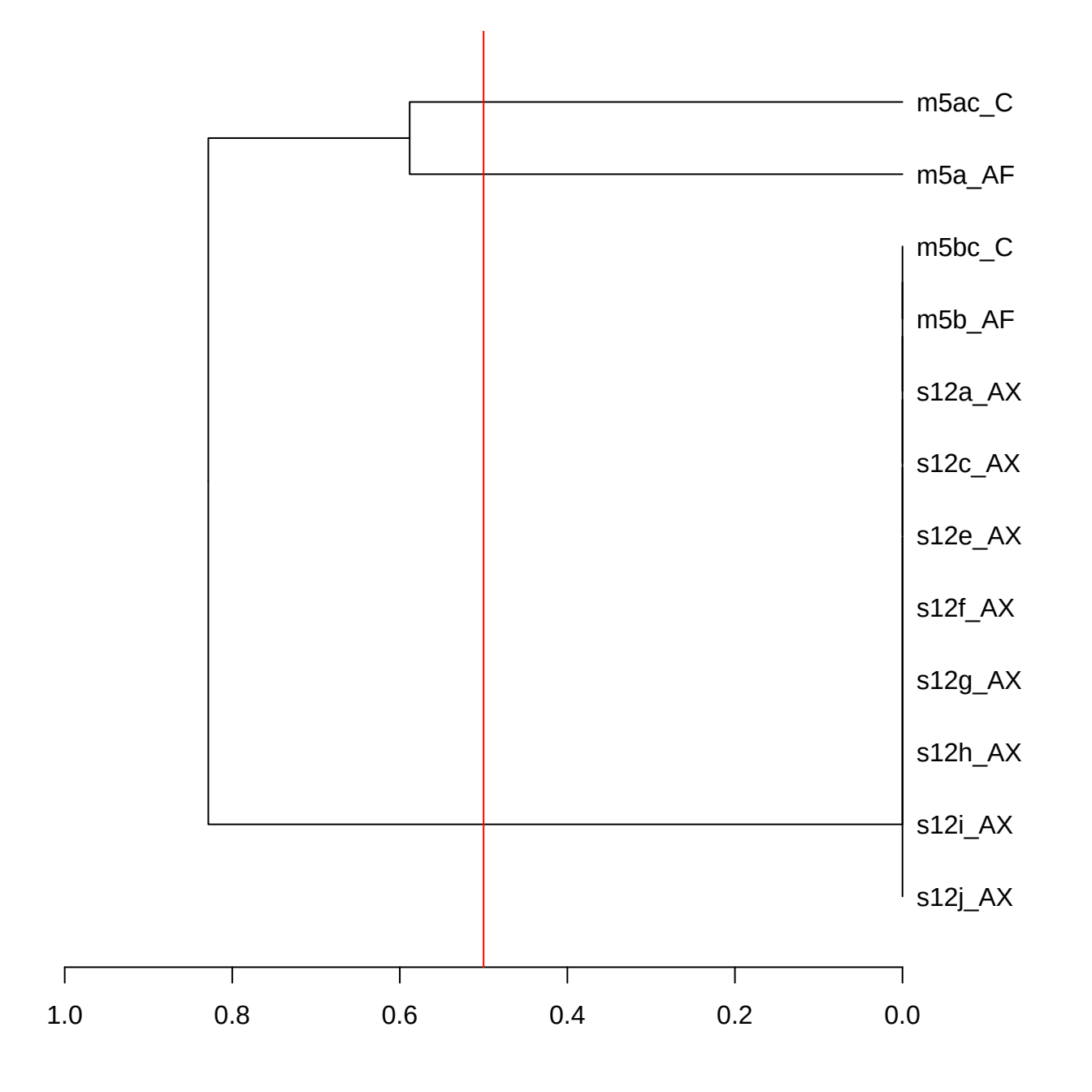
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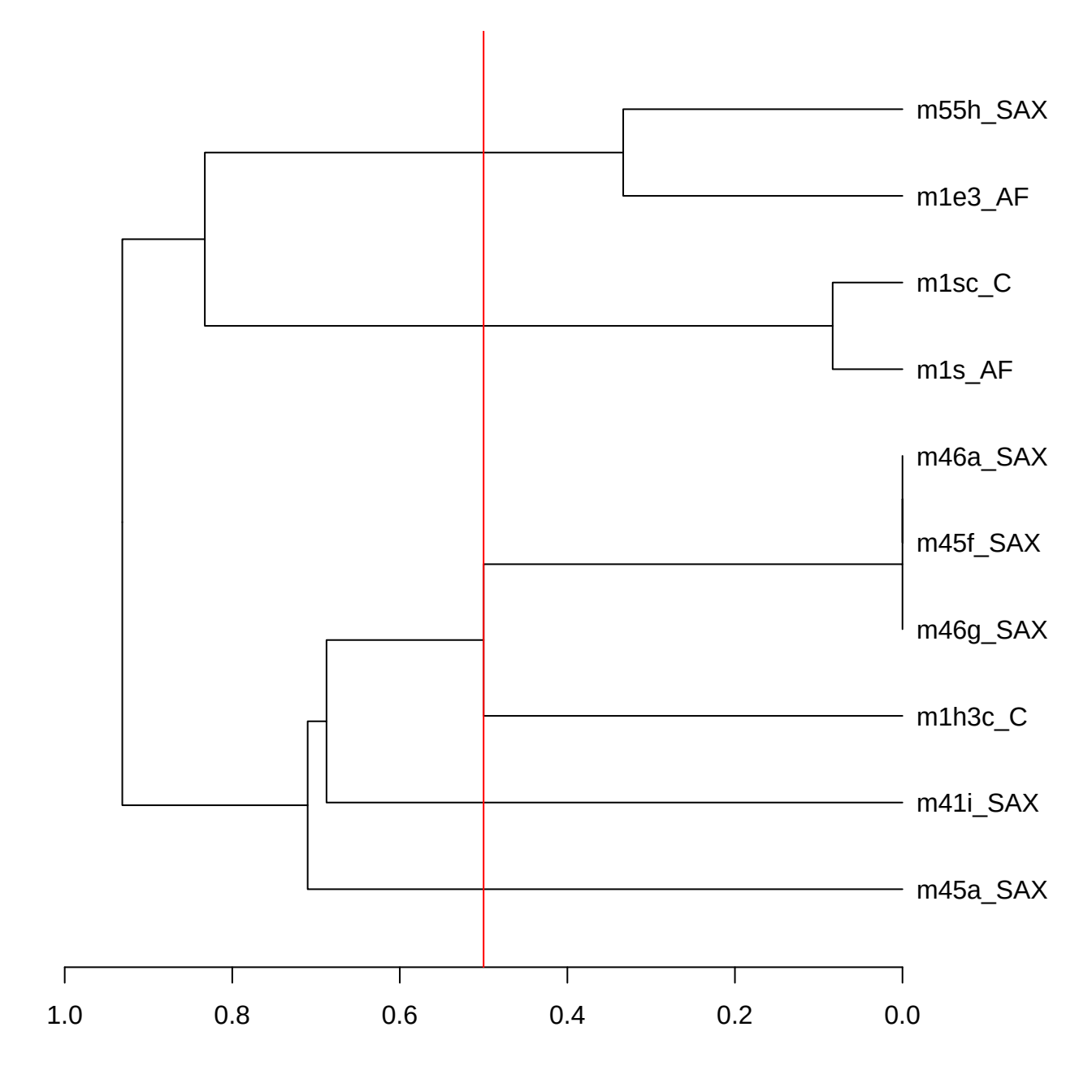
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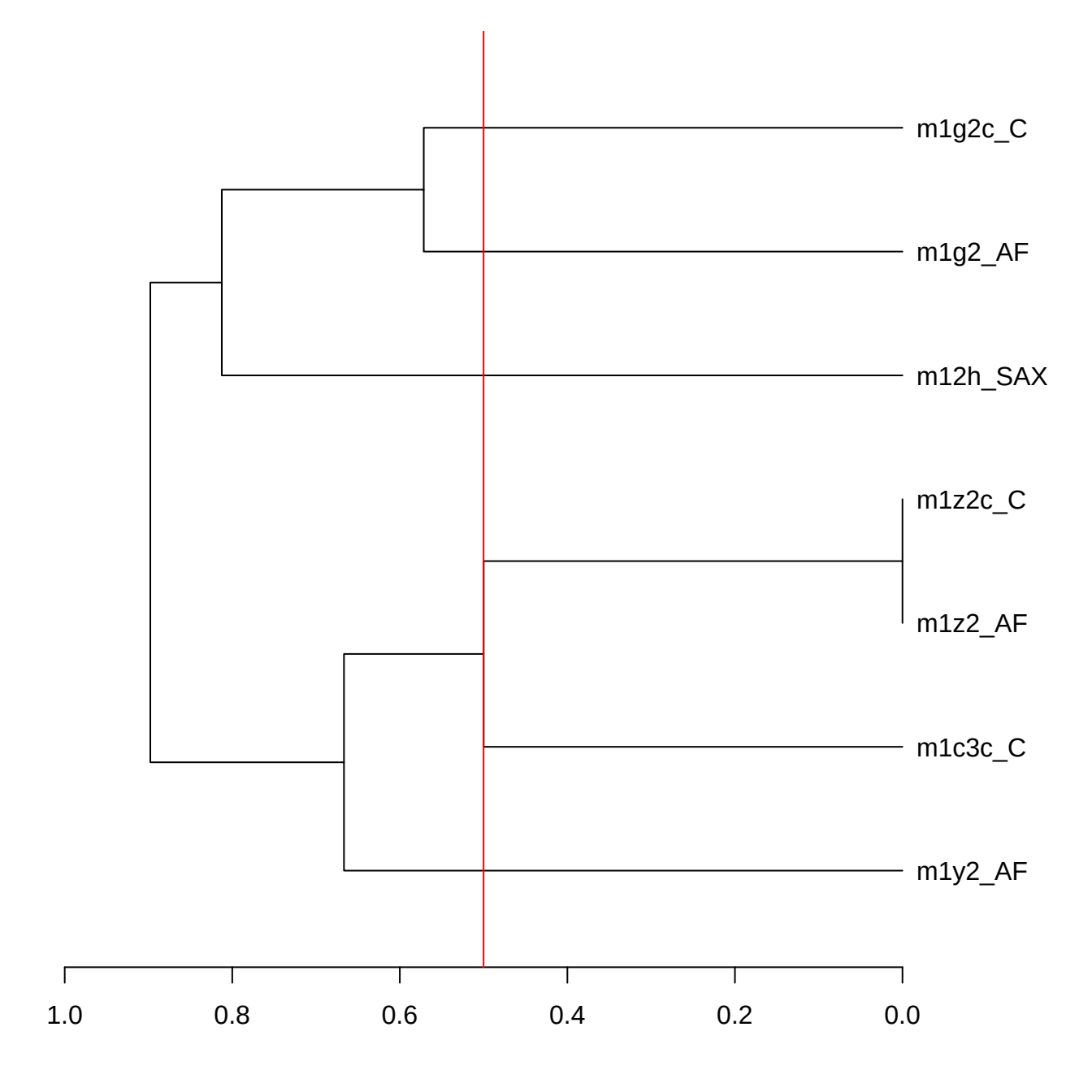
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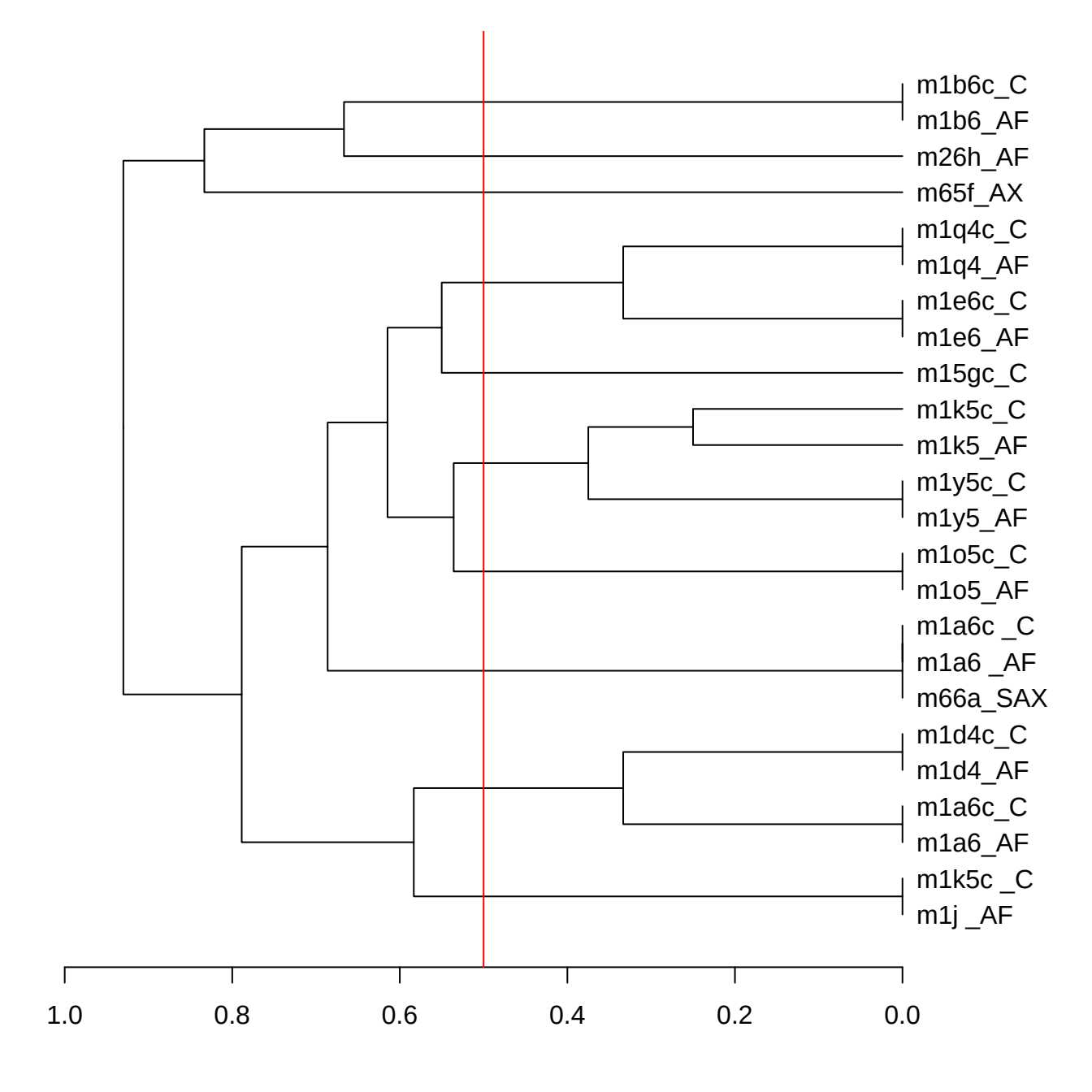
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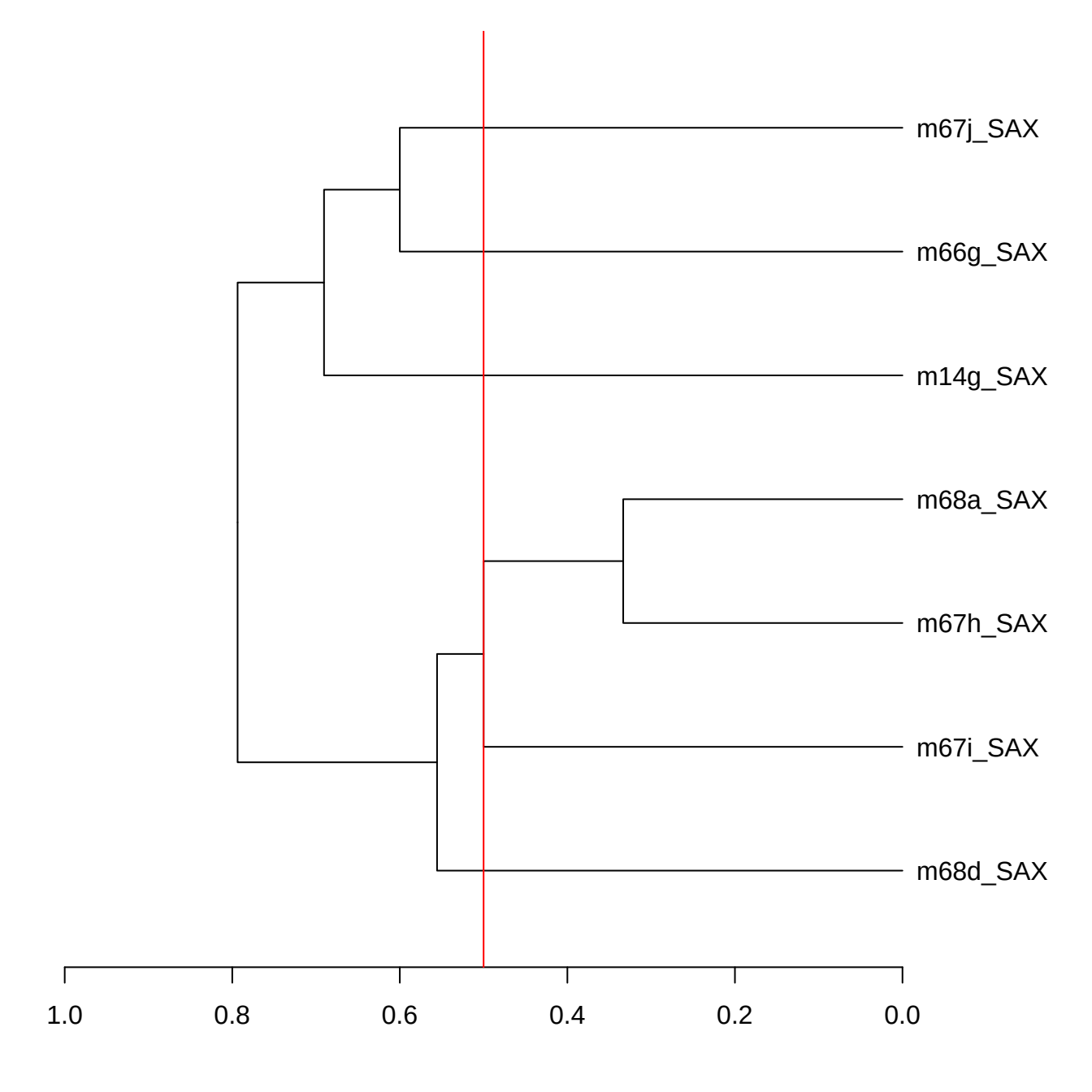
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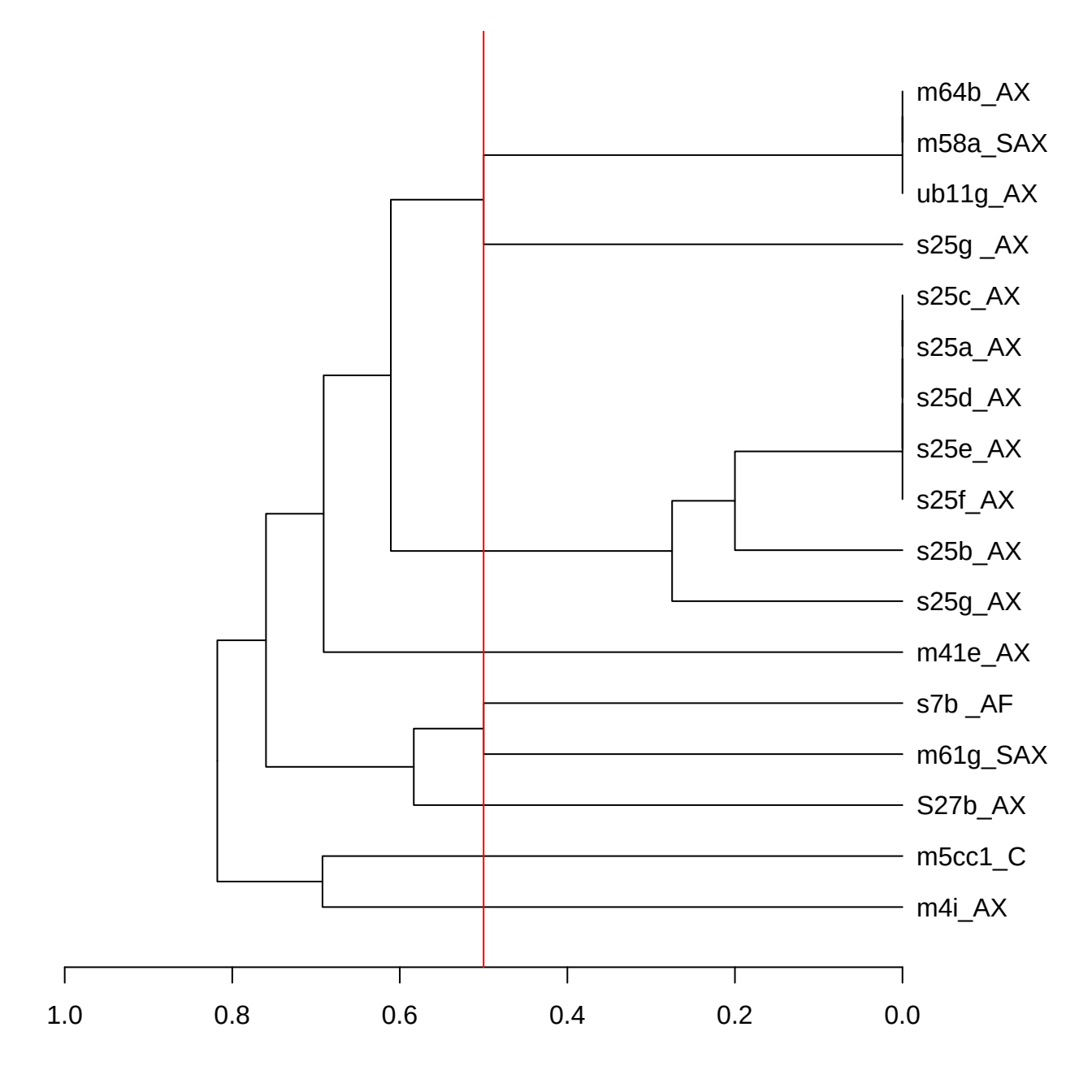
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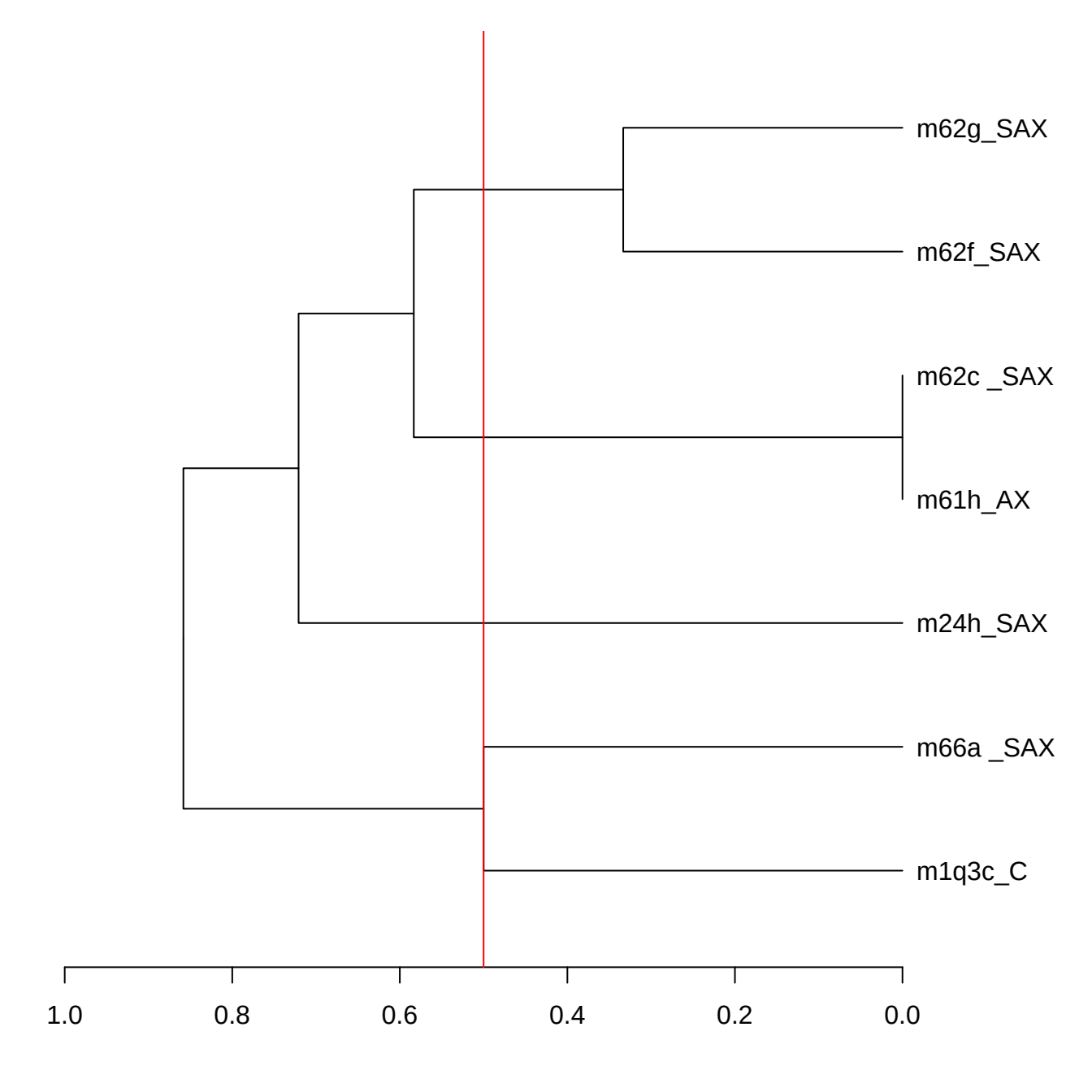
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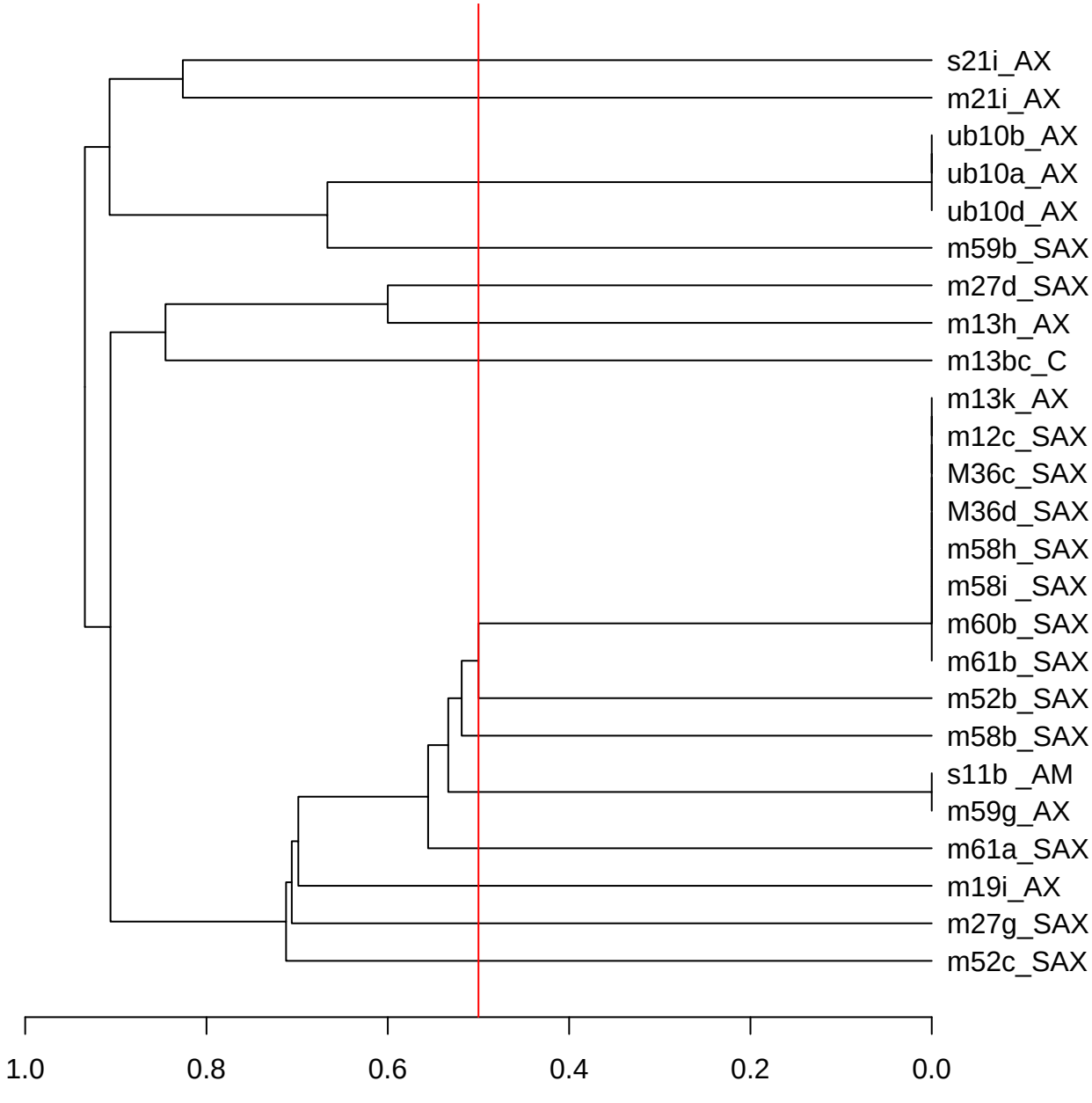
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m60b_SAX
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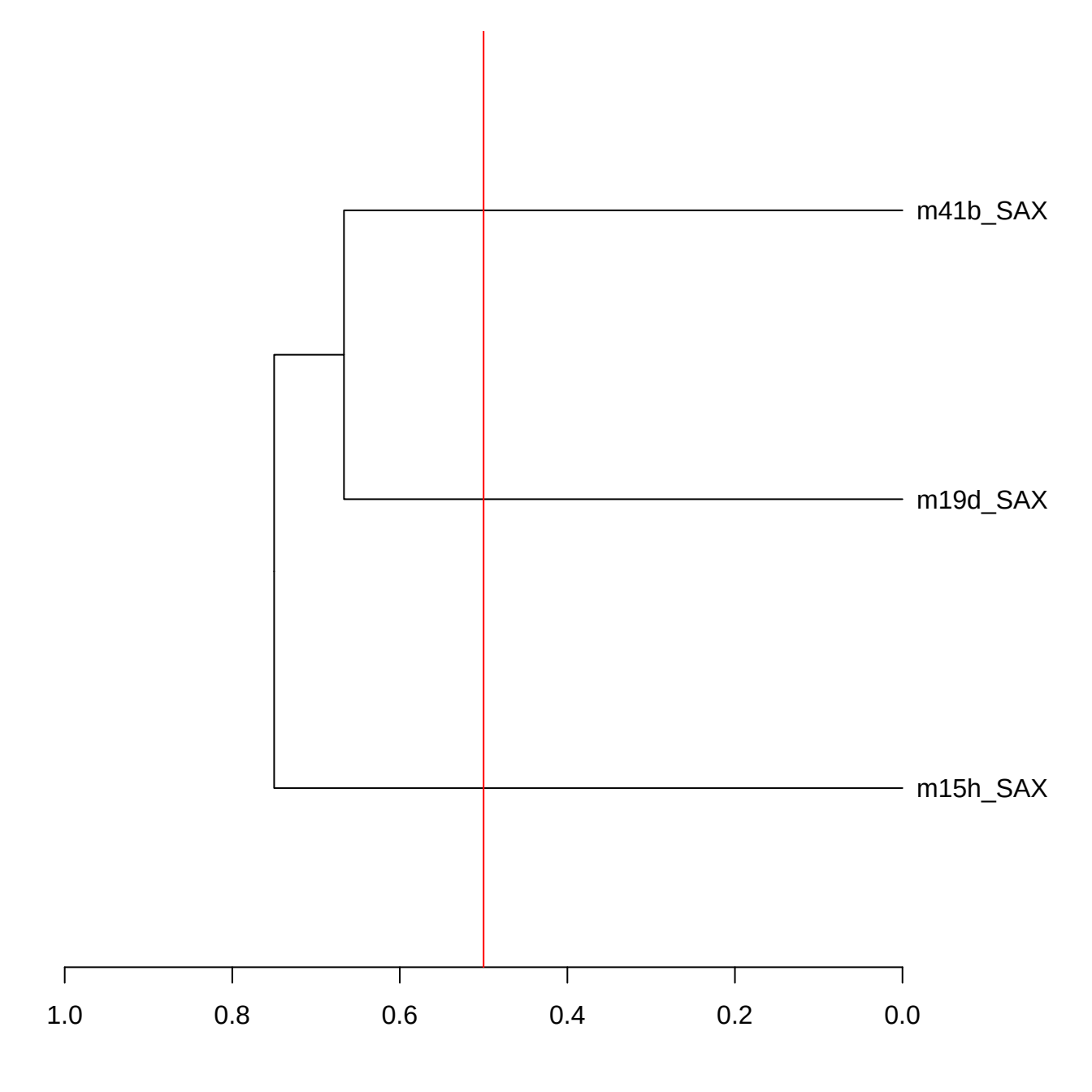
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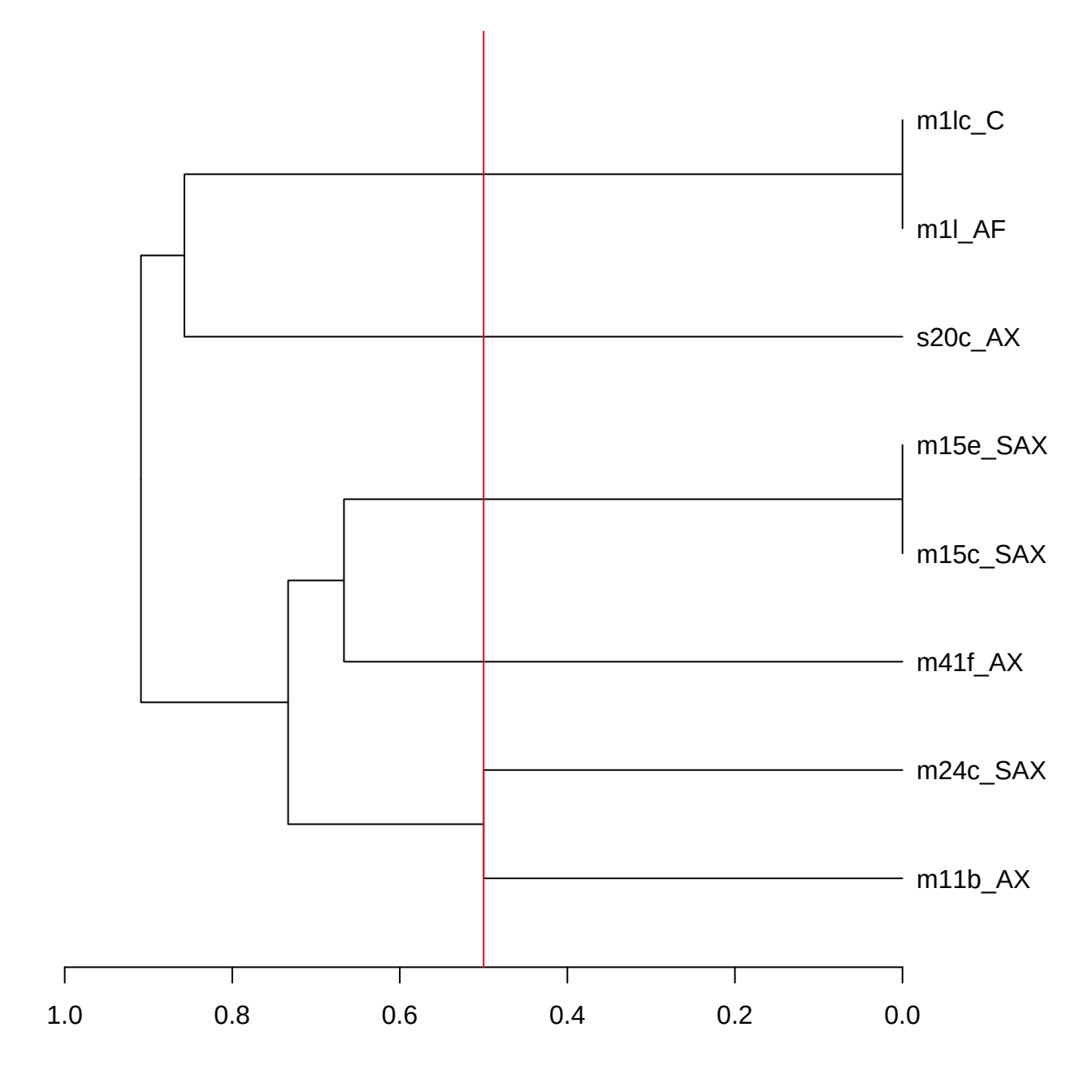
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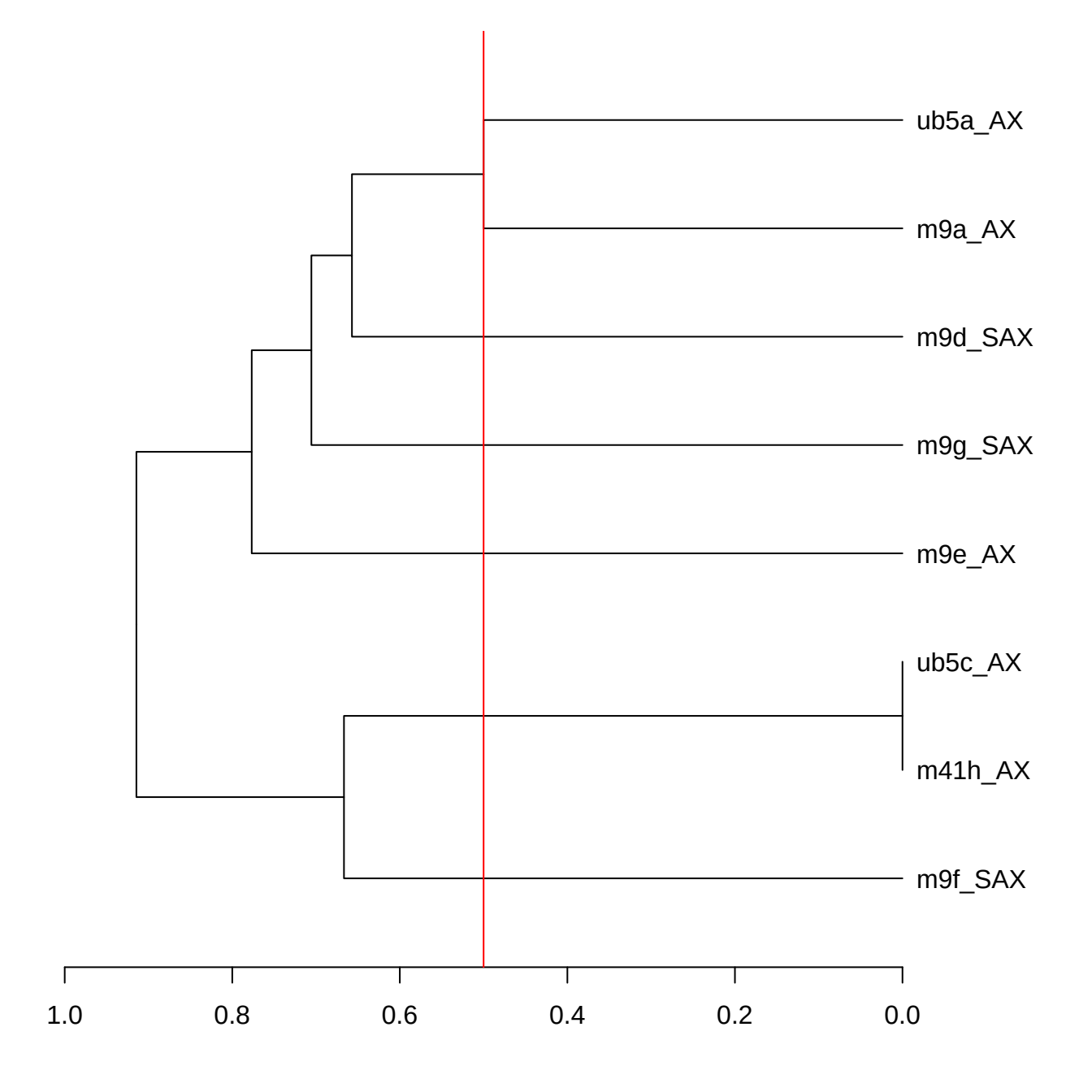
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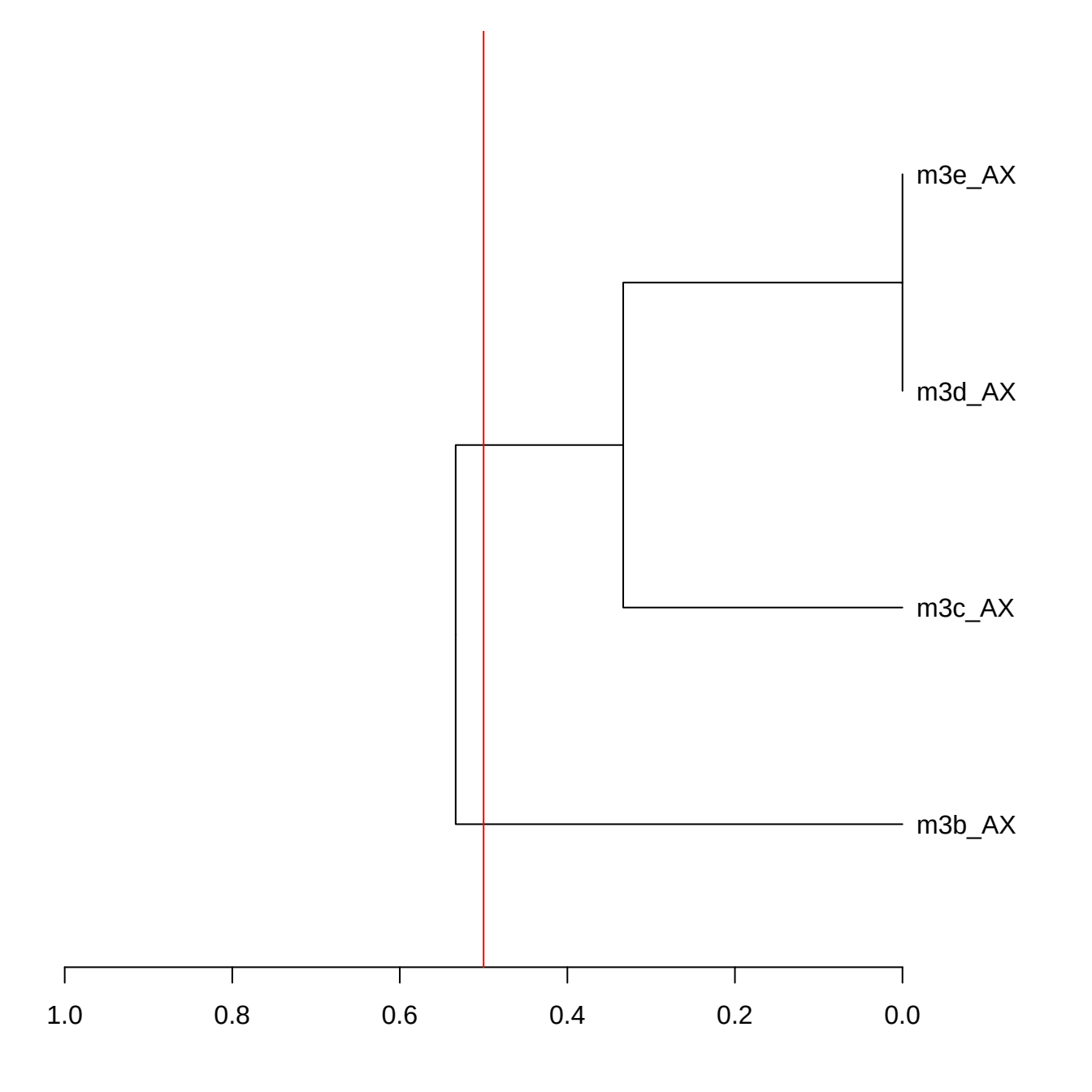
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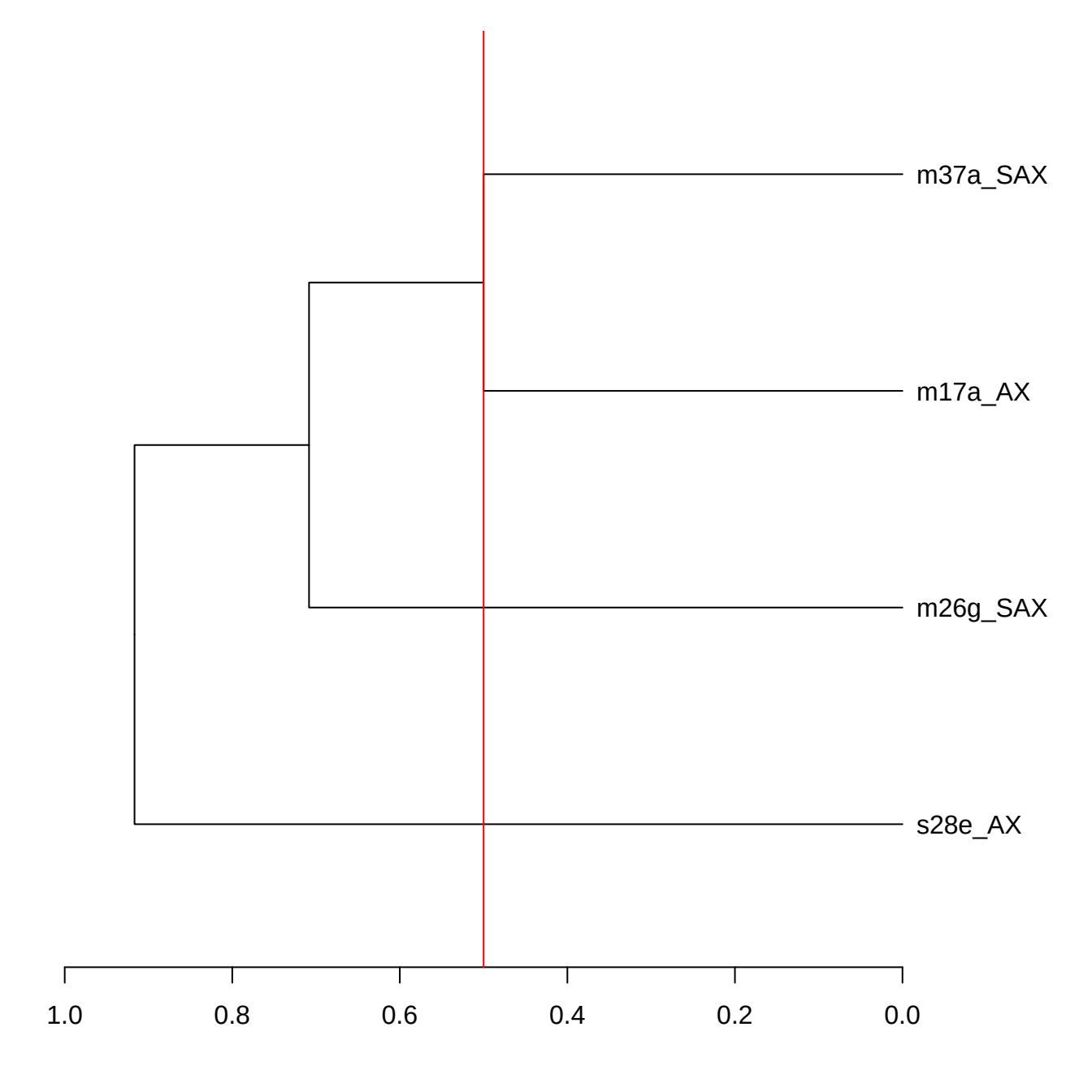
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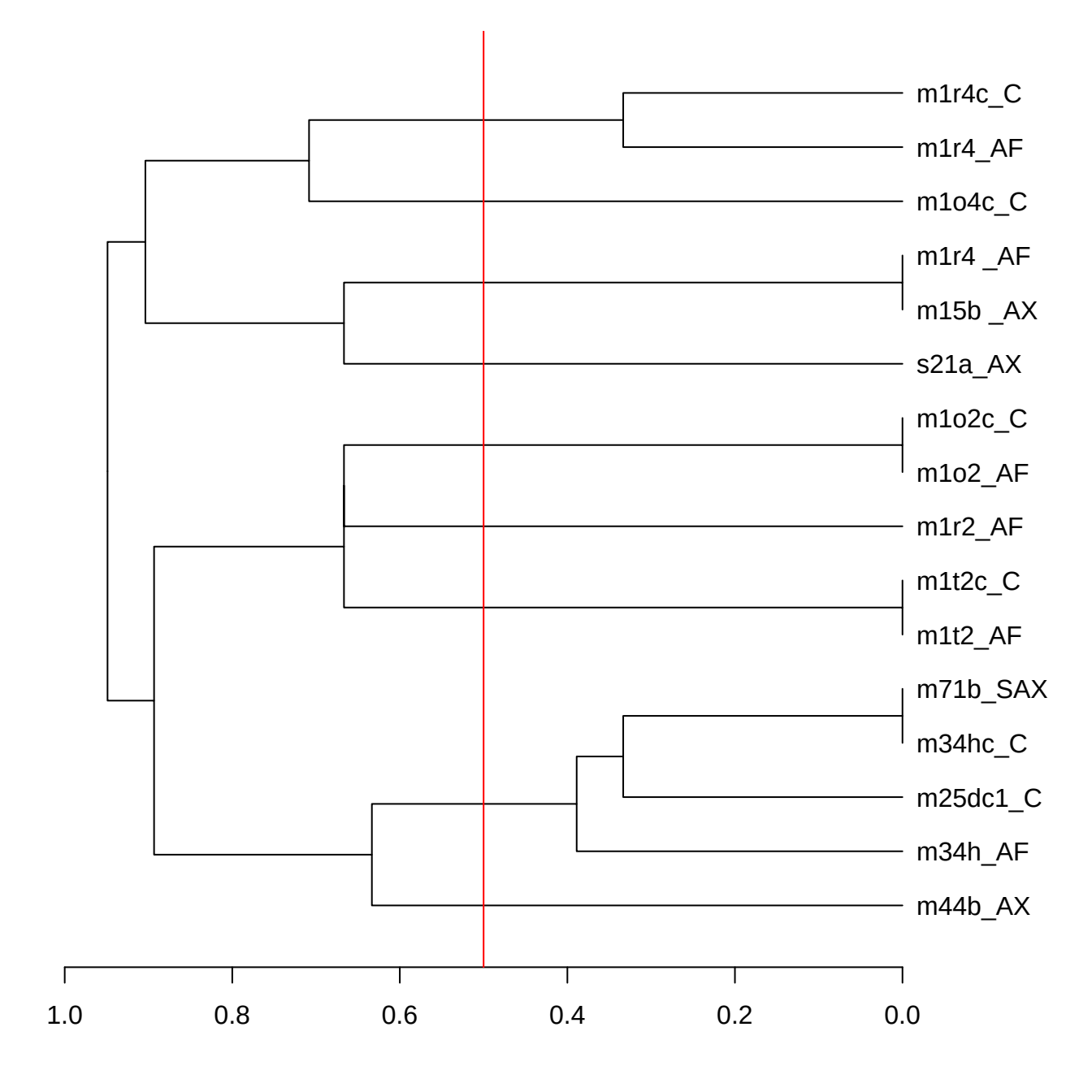
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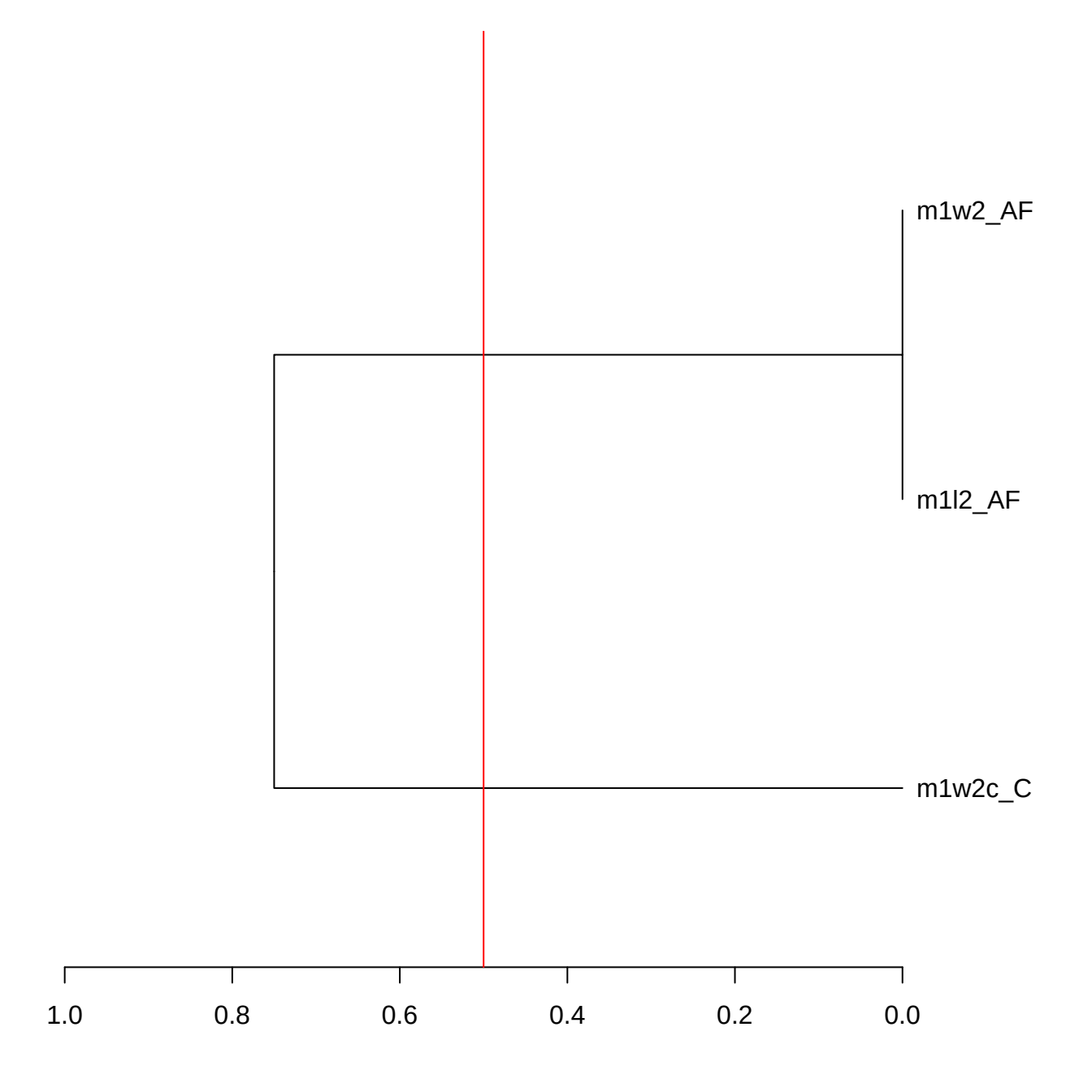
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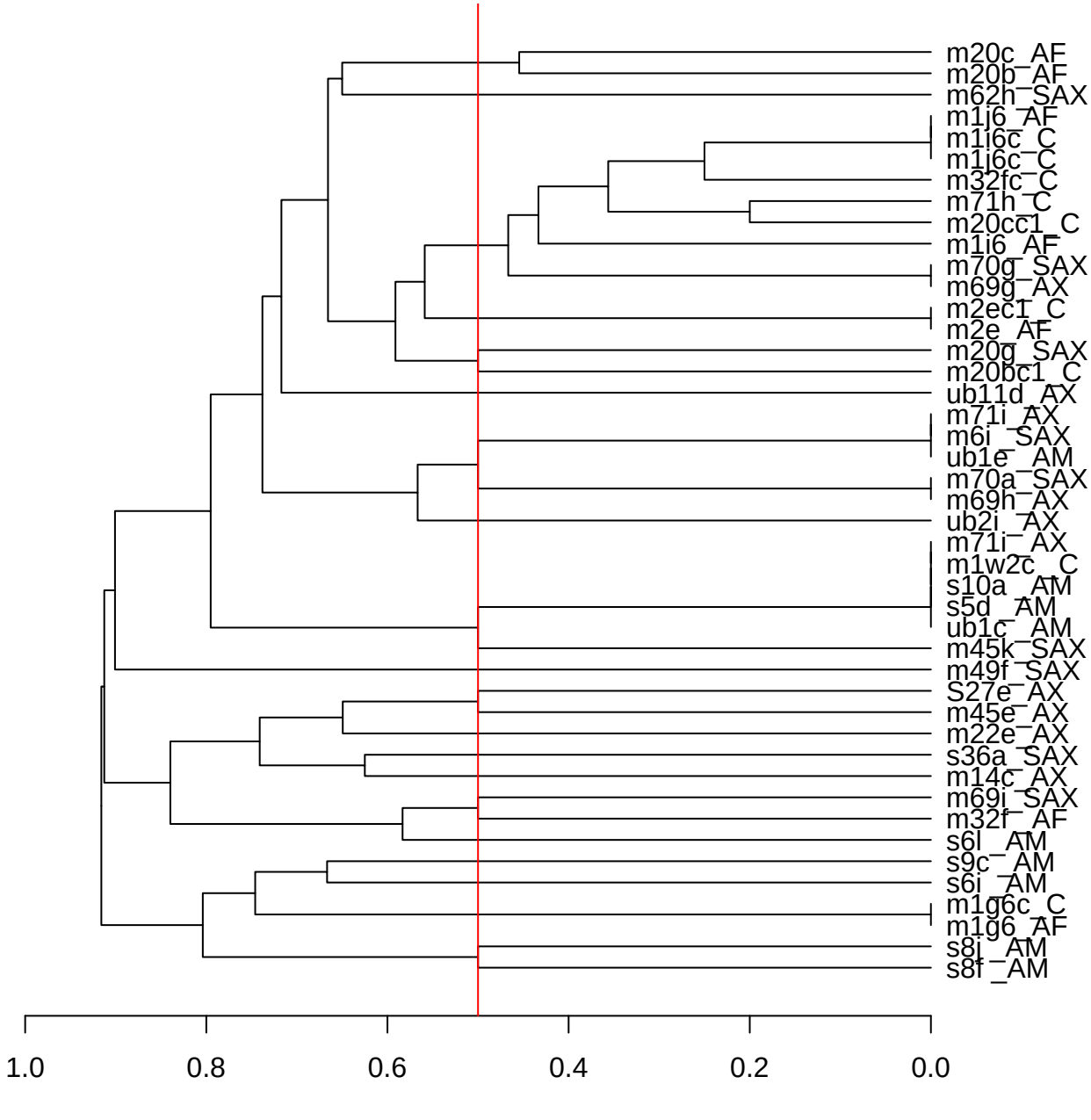
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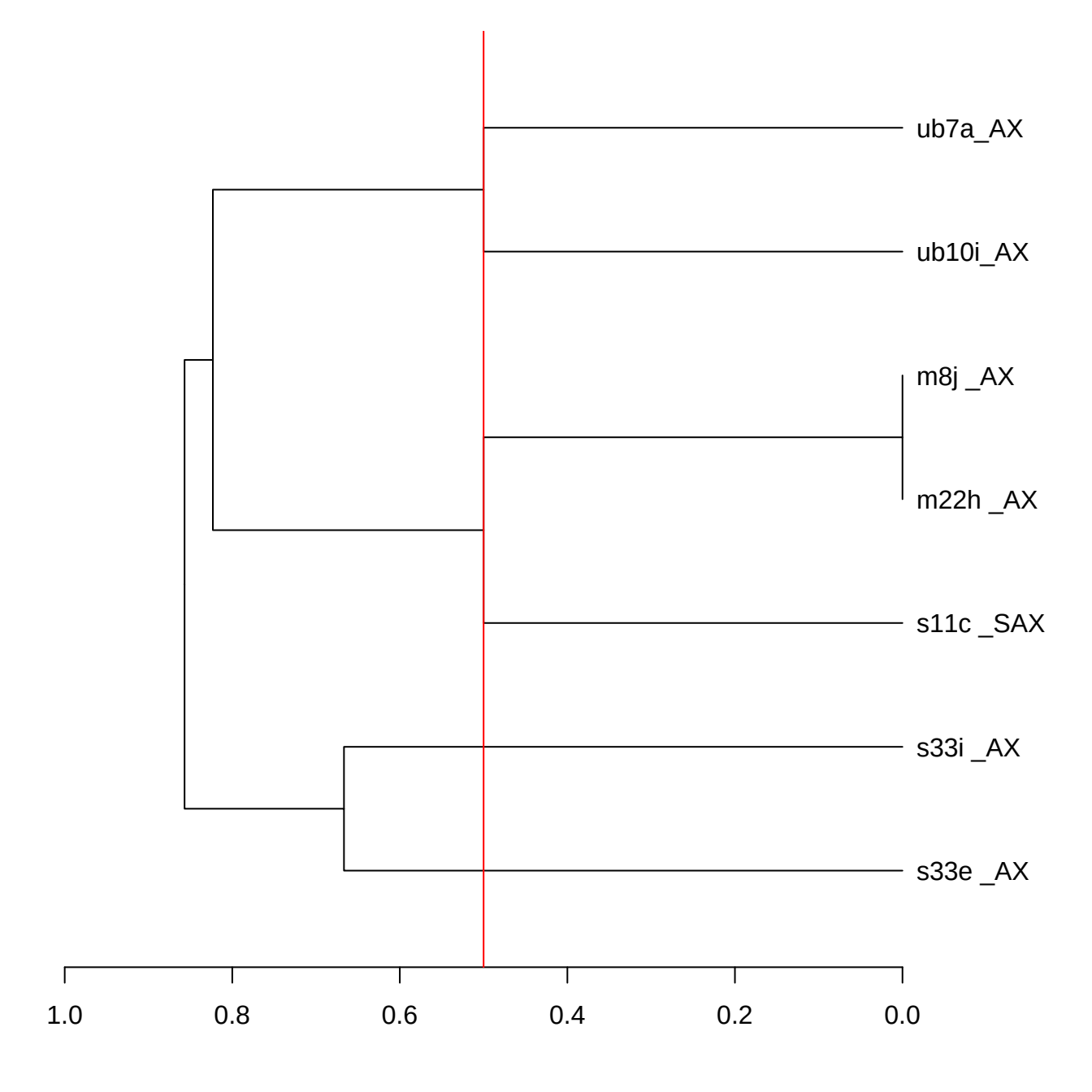
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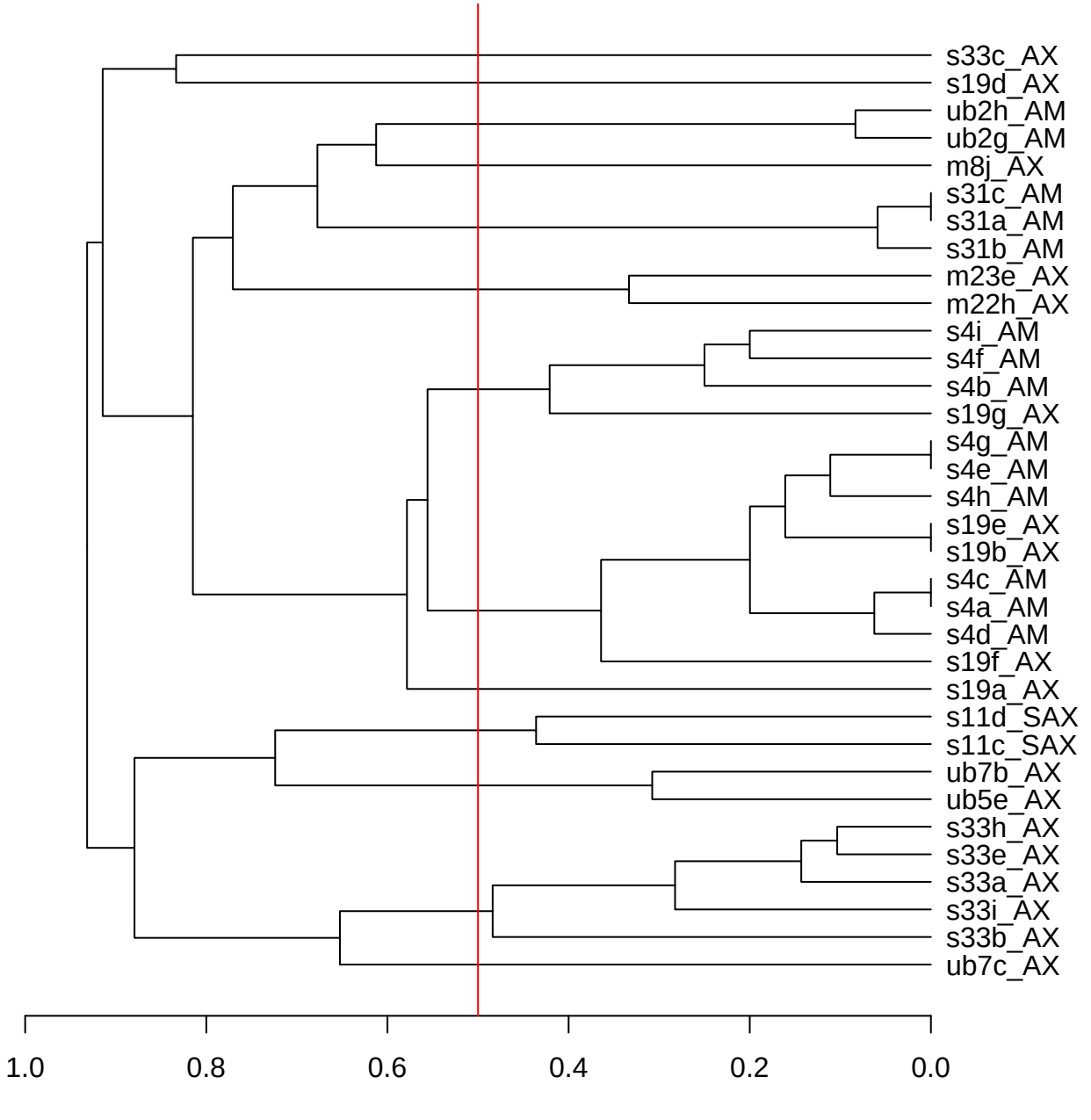
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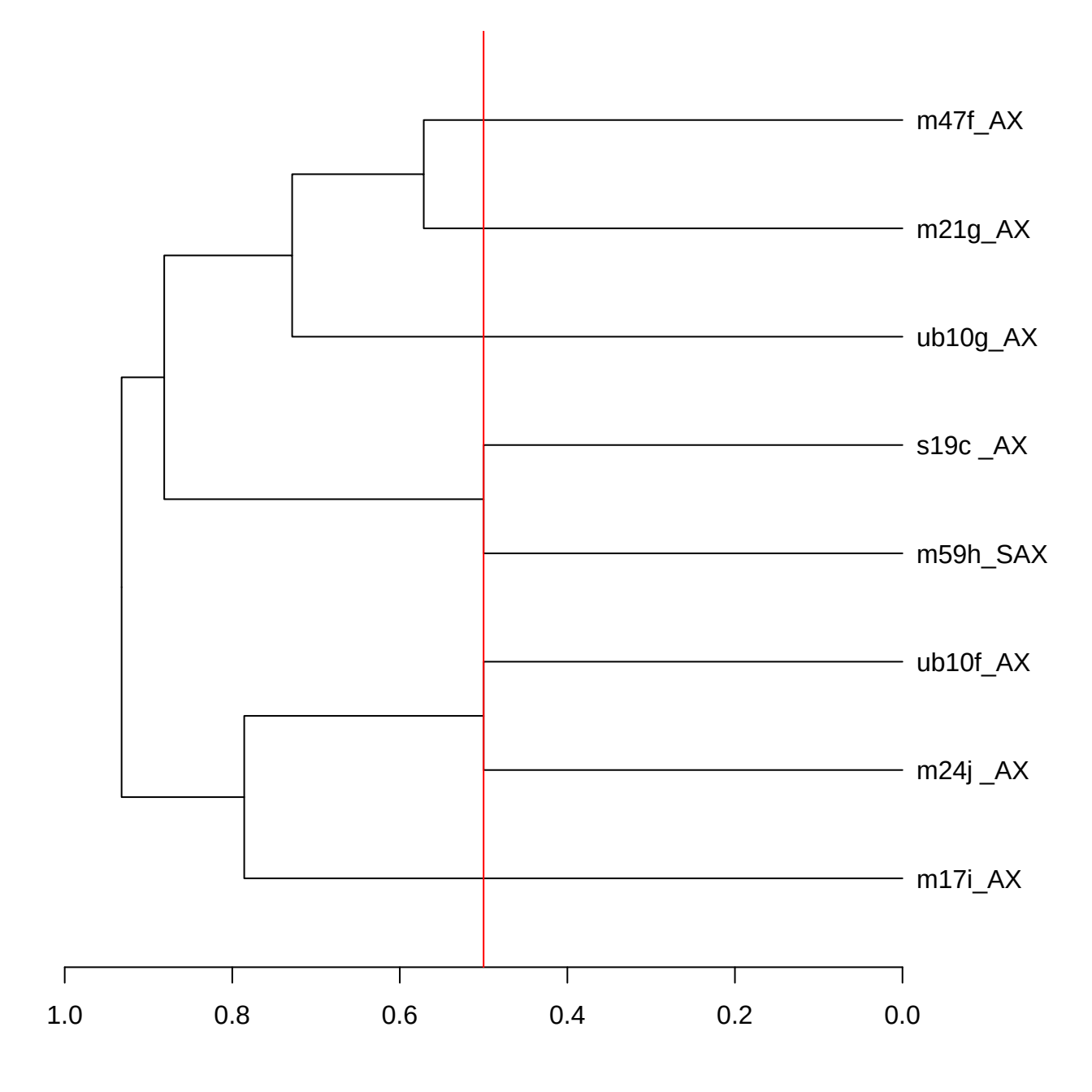
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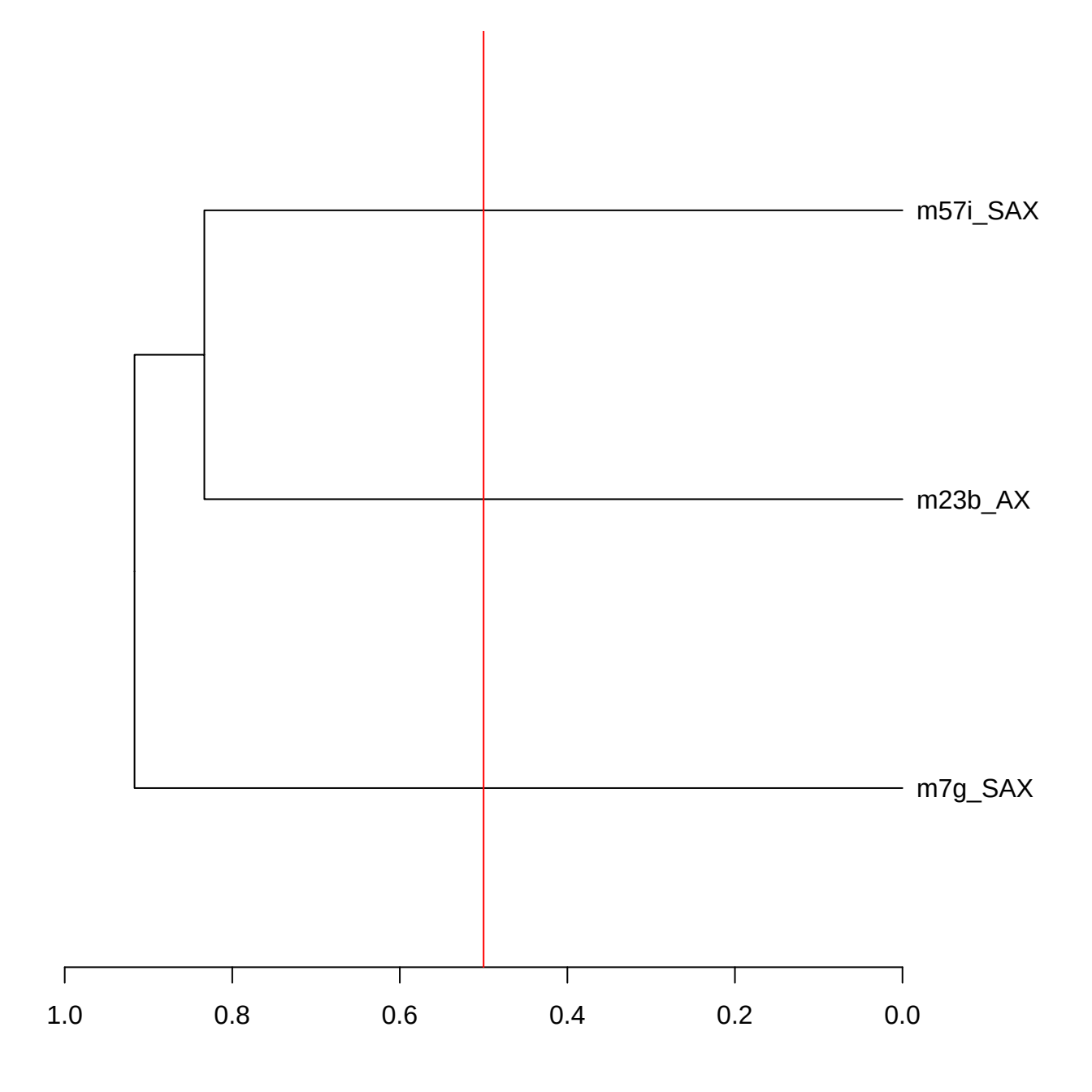
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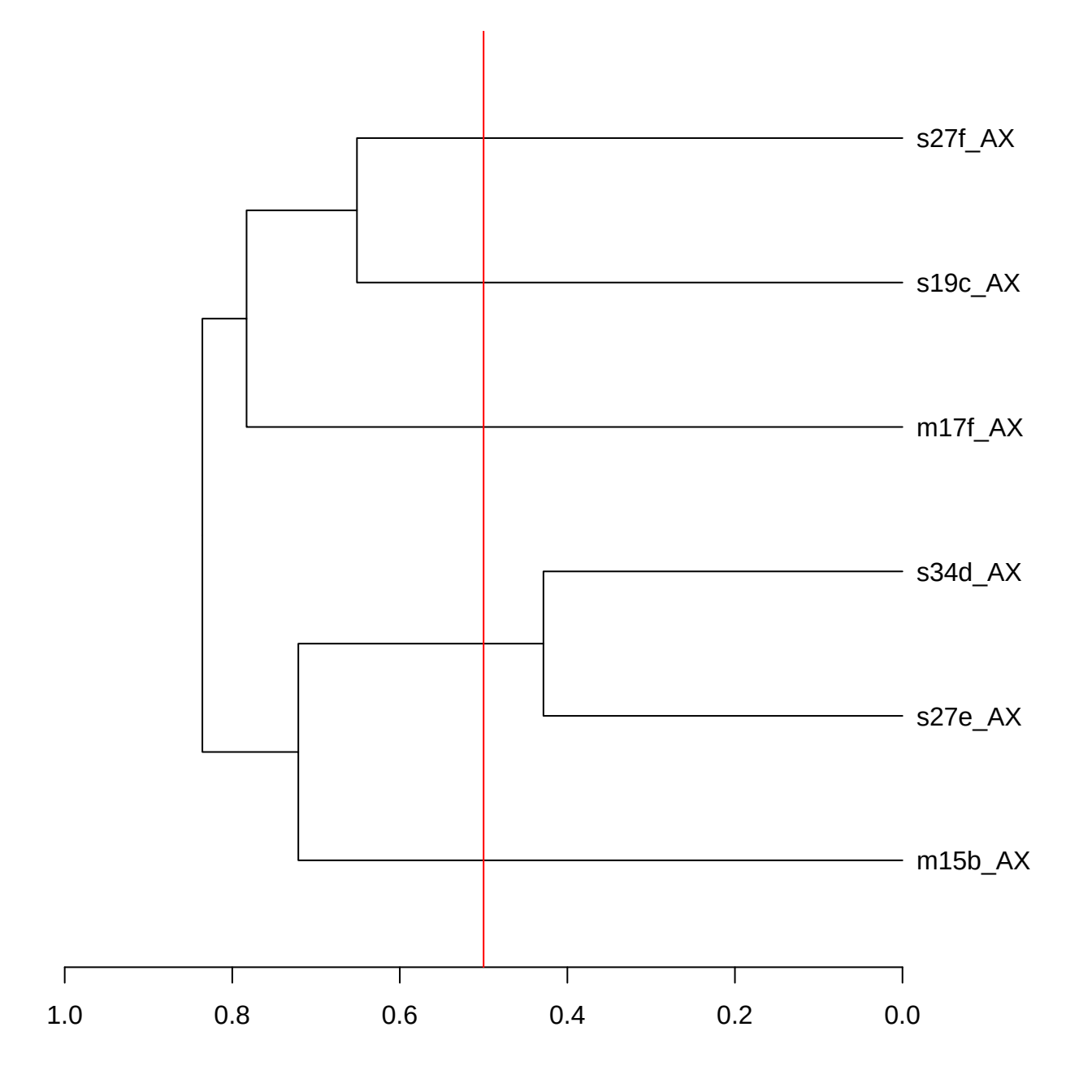
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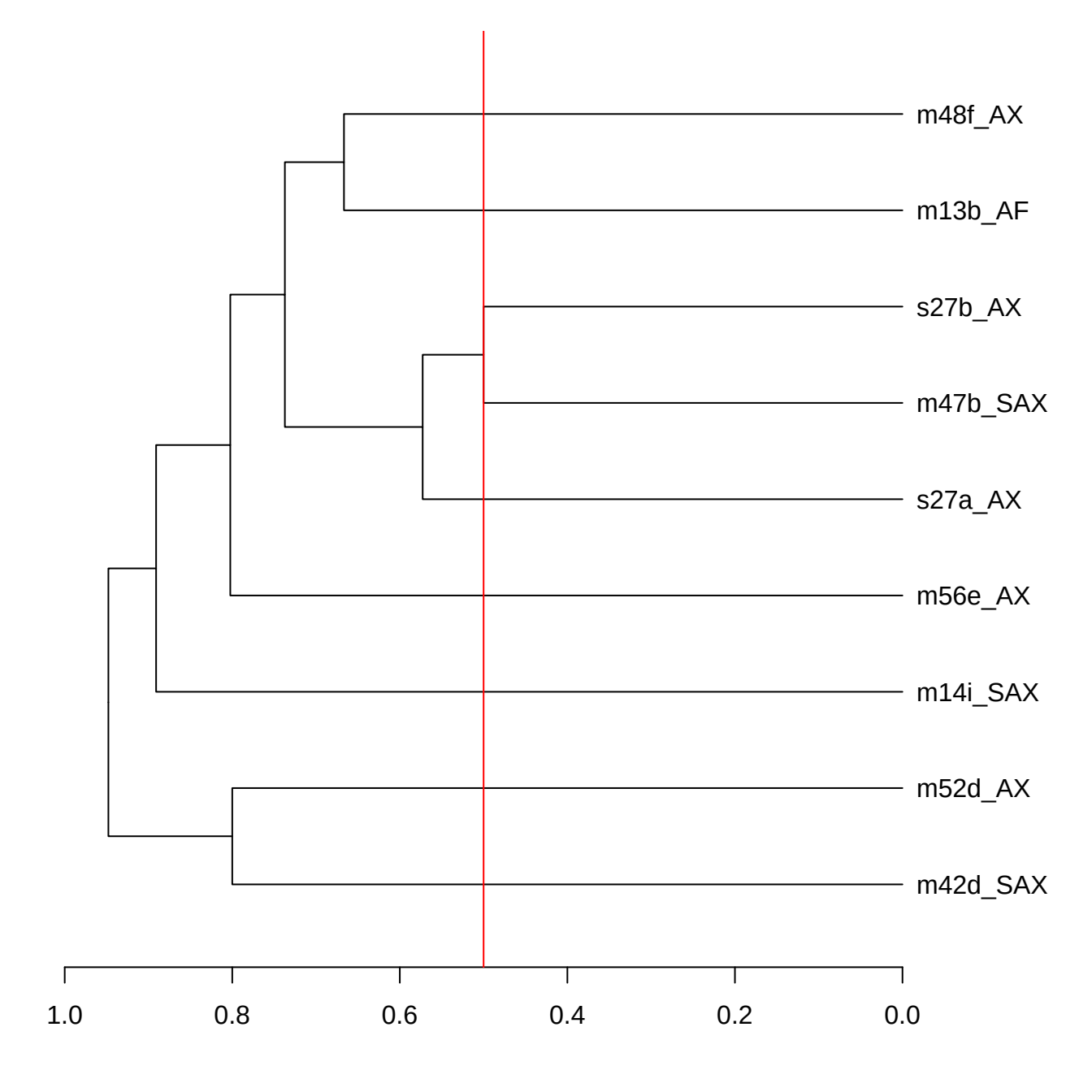
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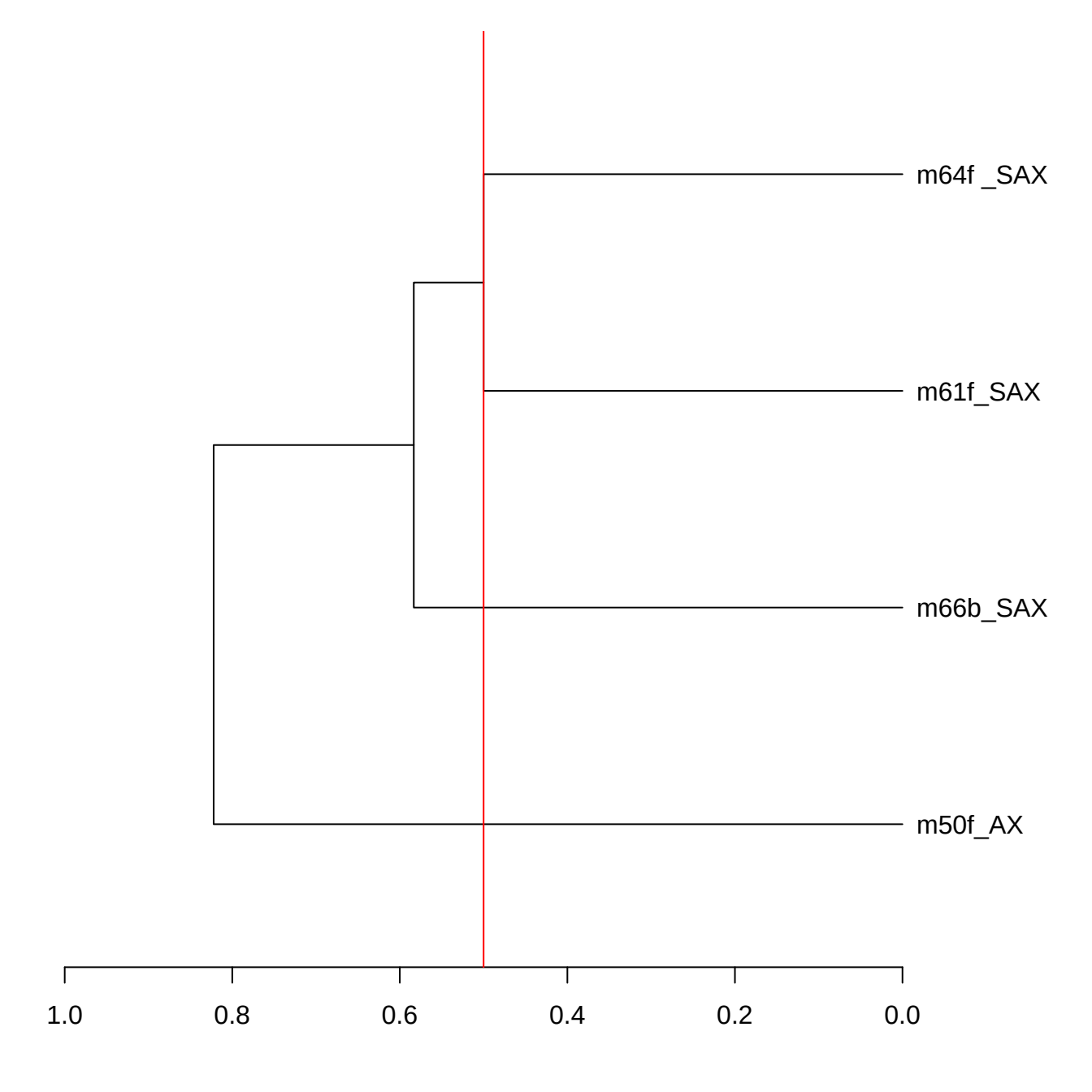
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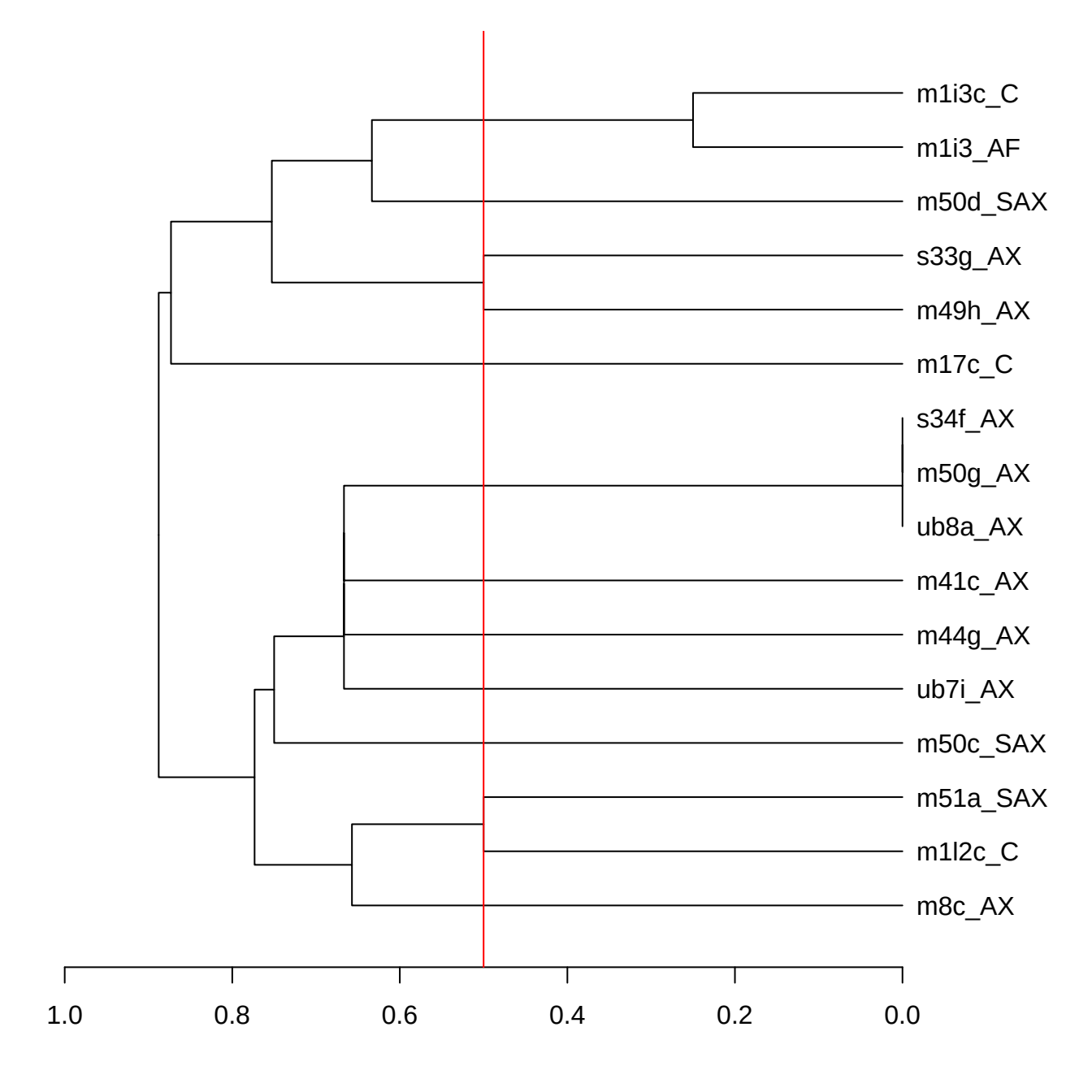
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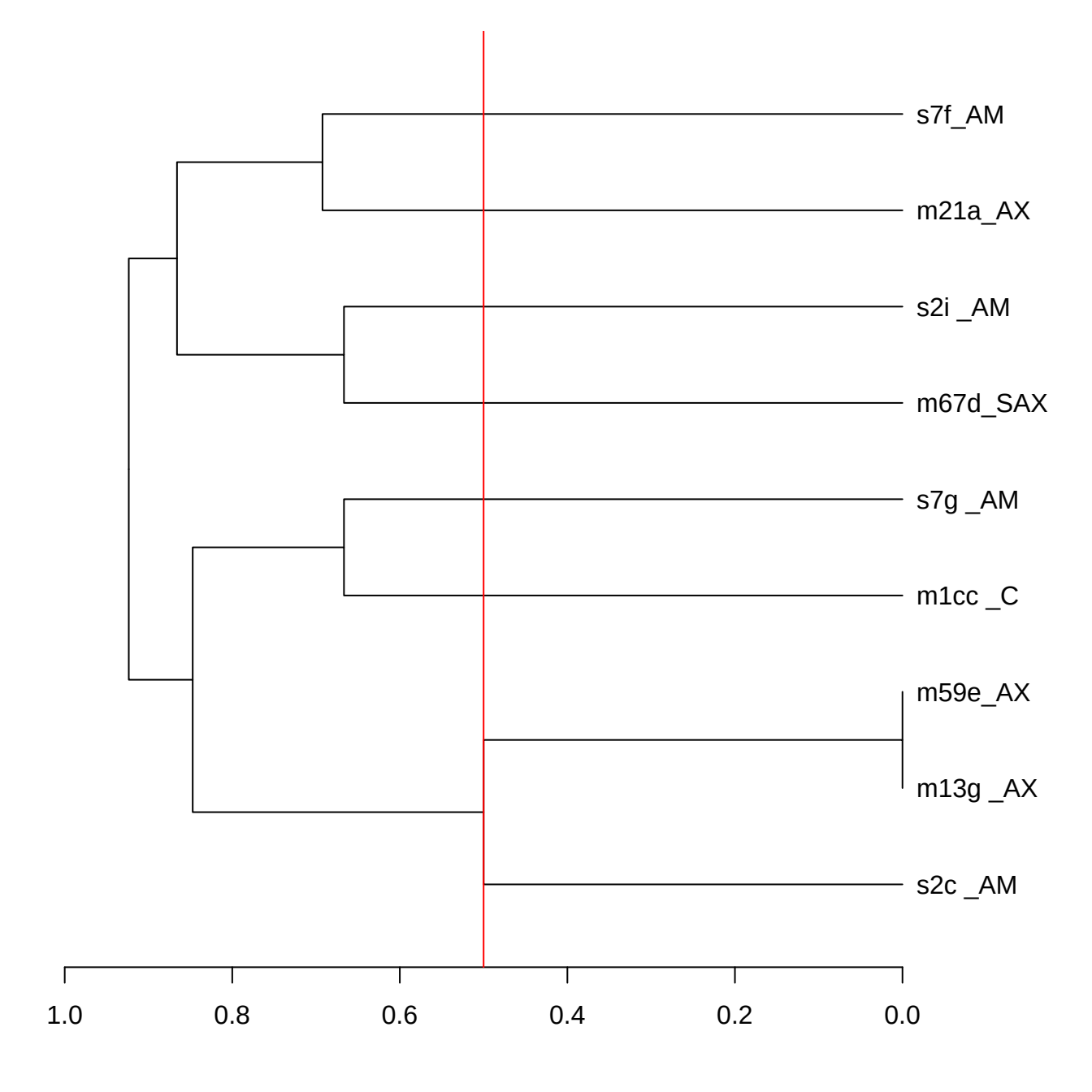
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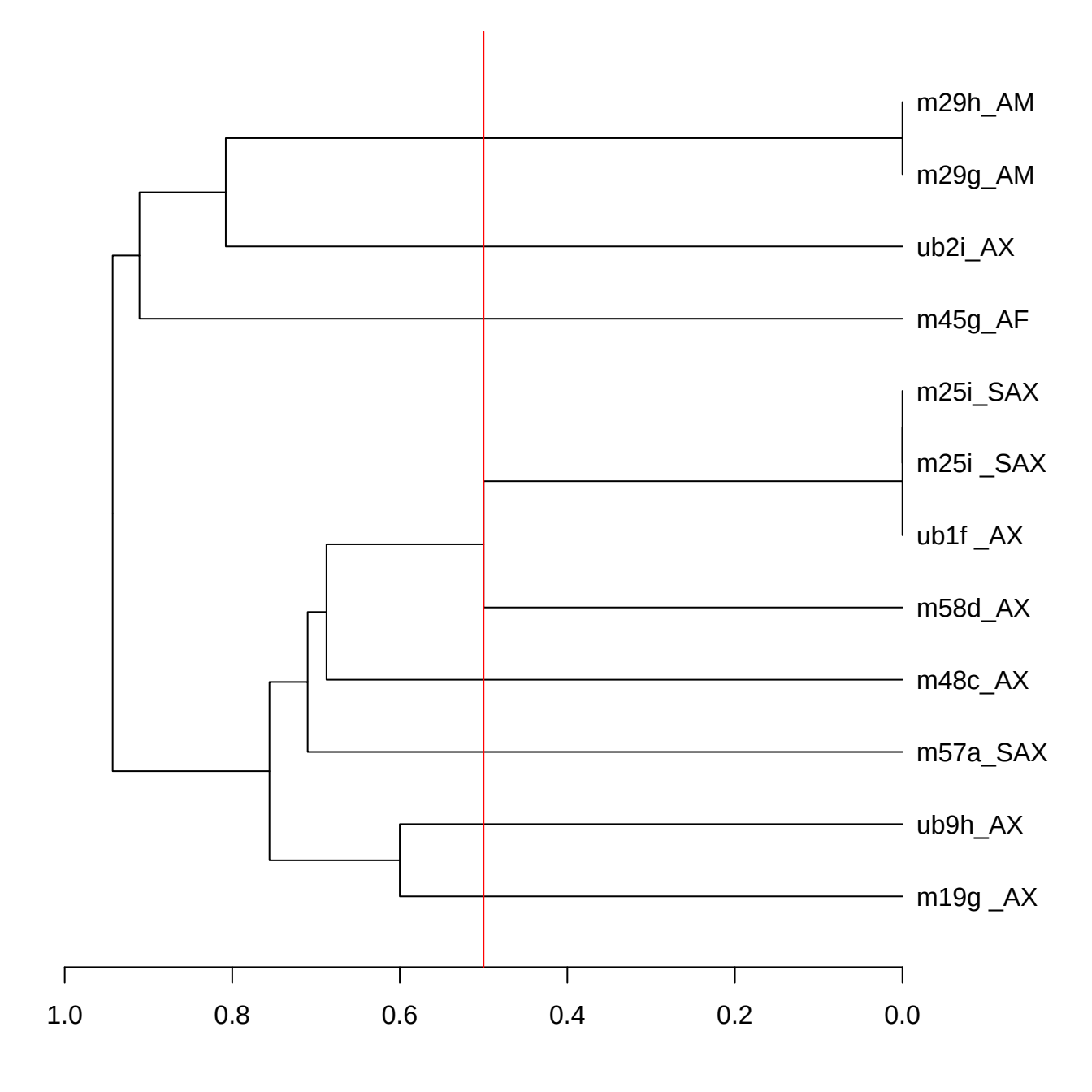
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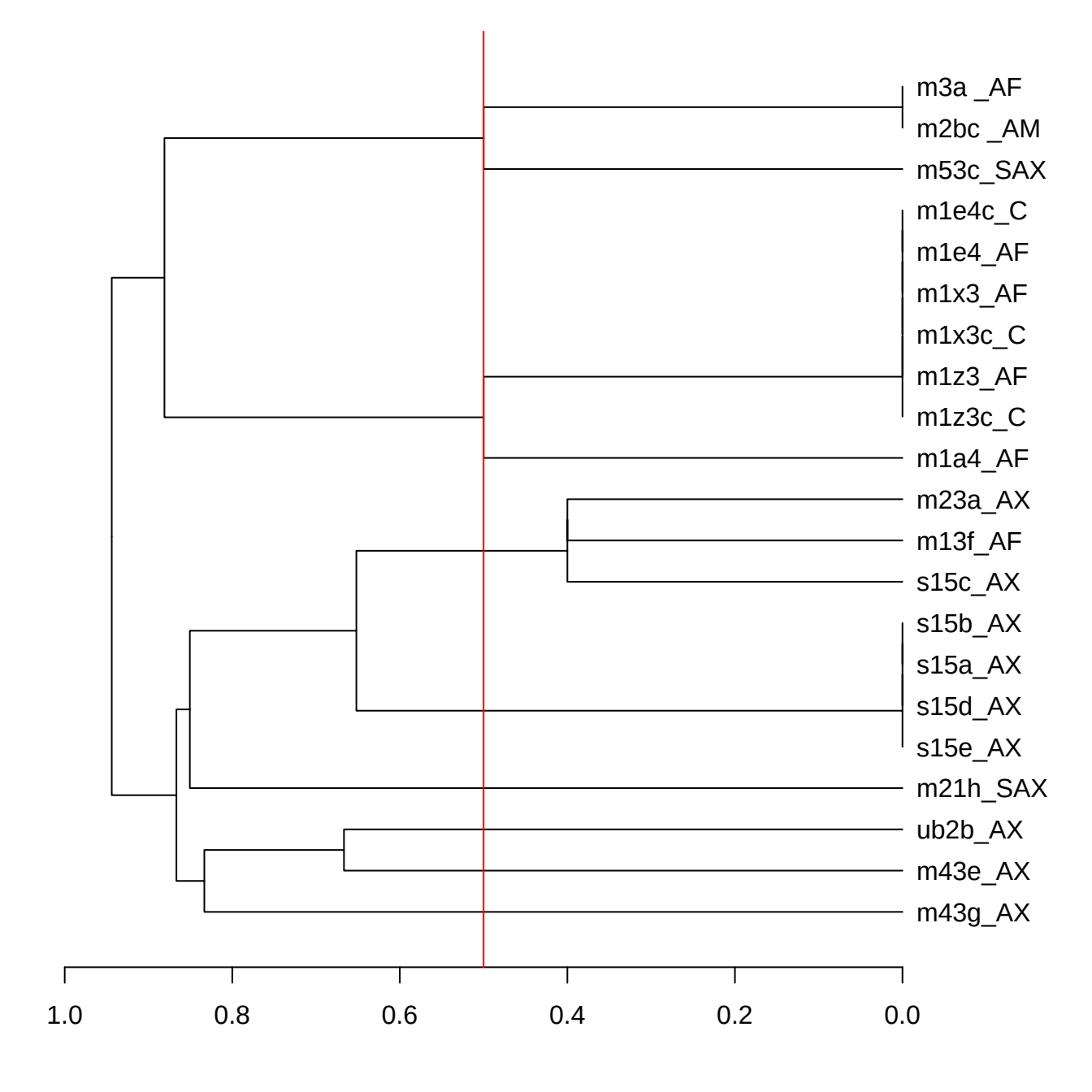
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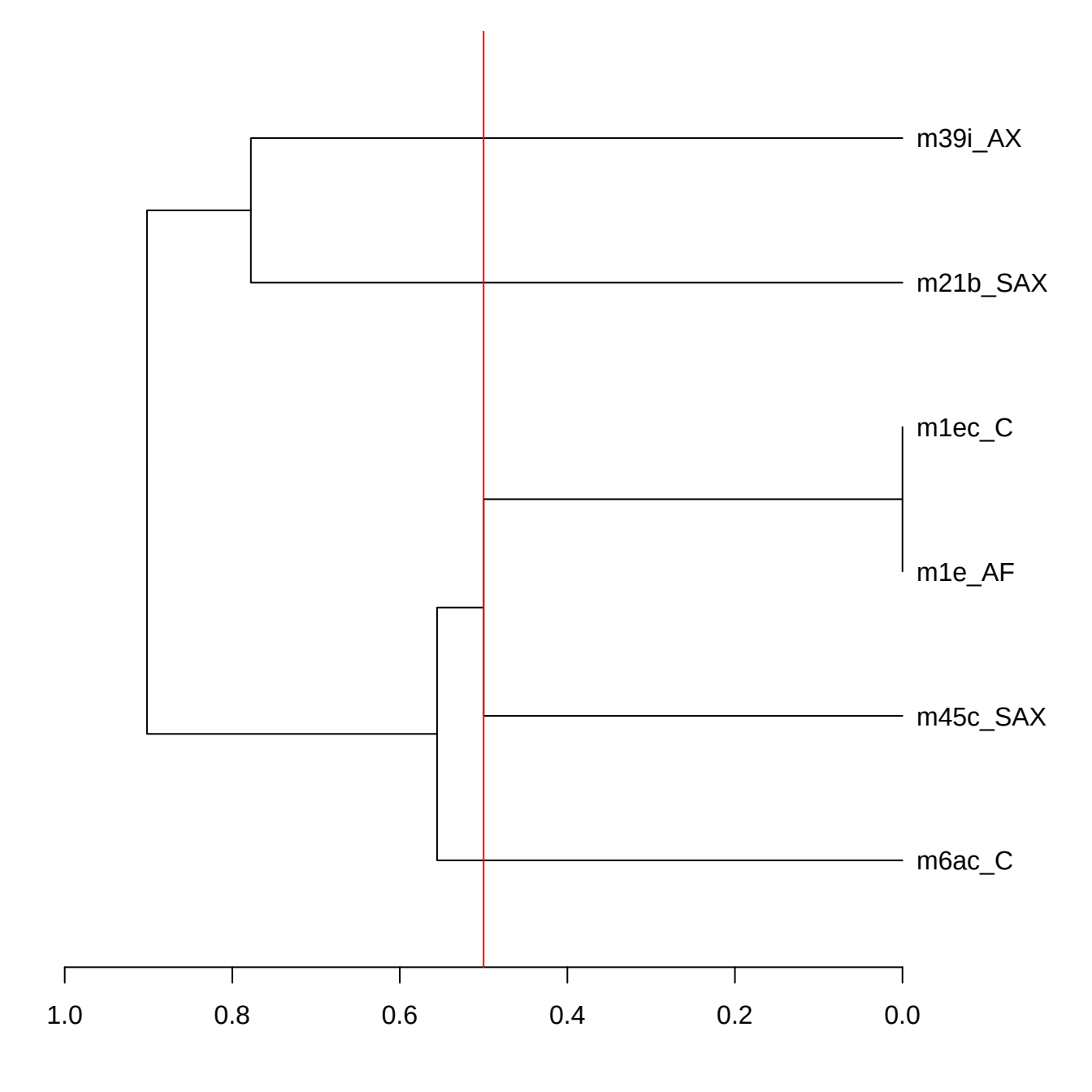
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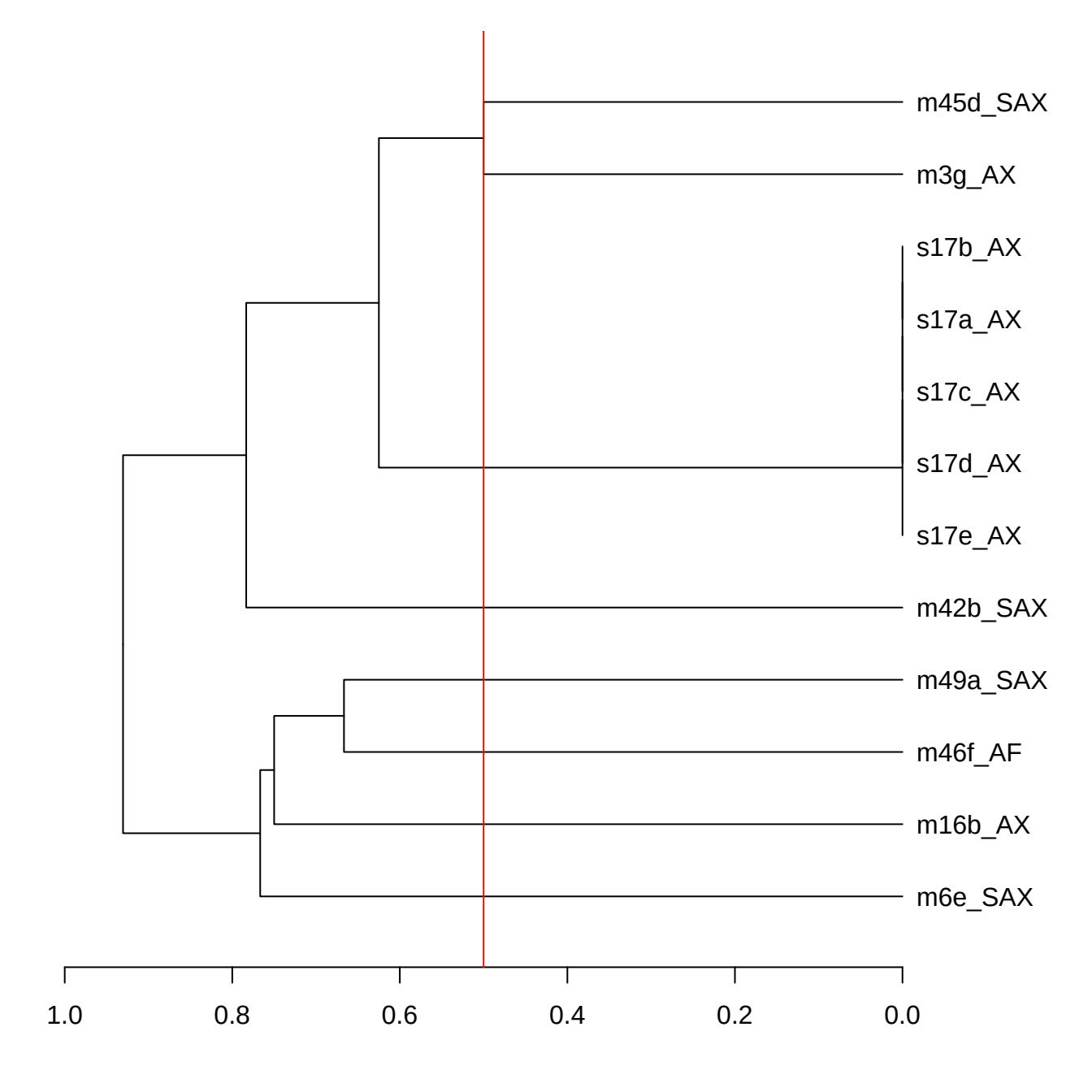
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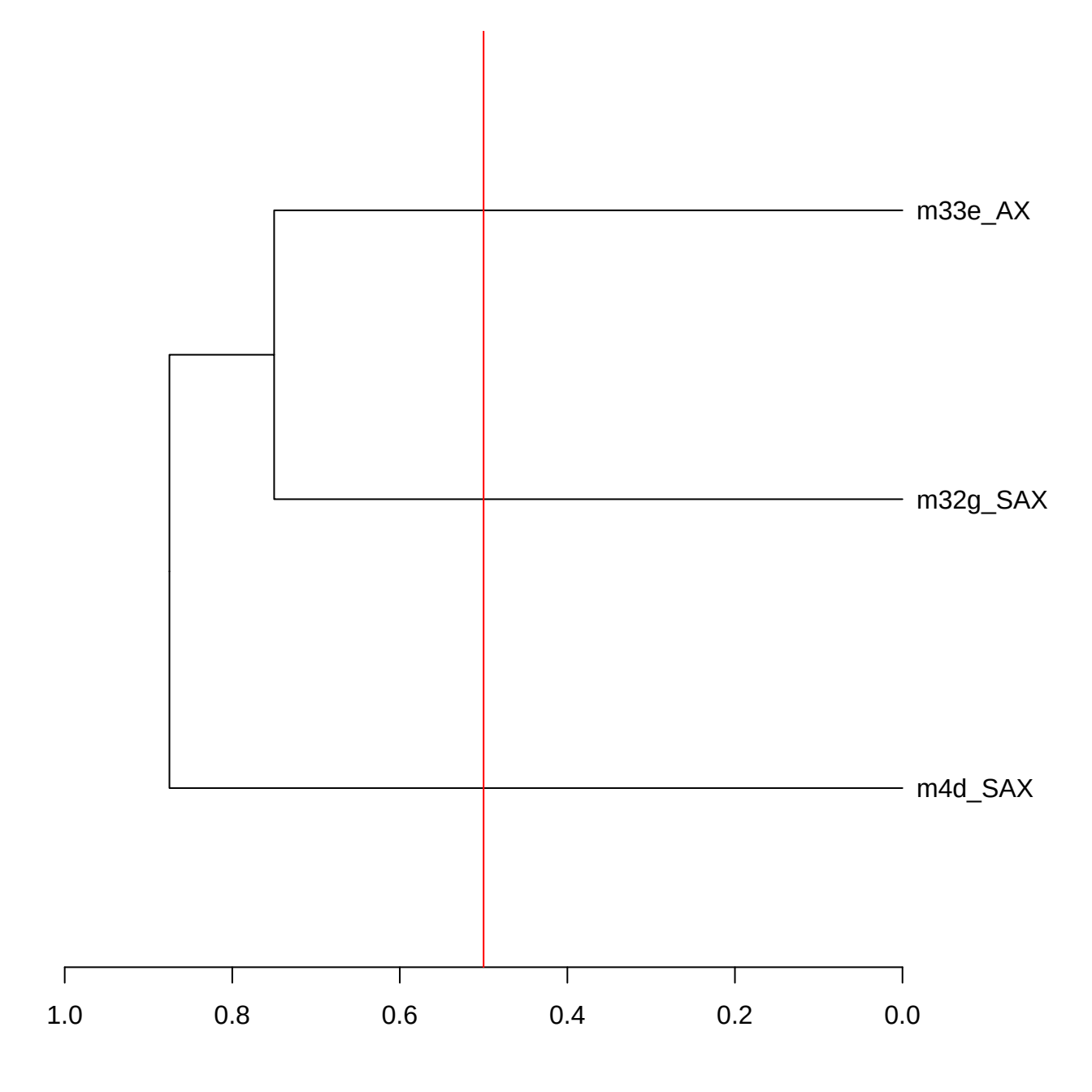
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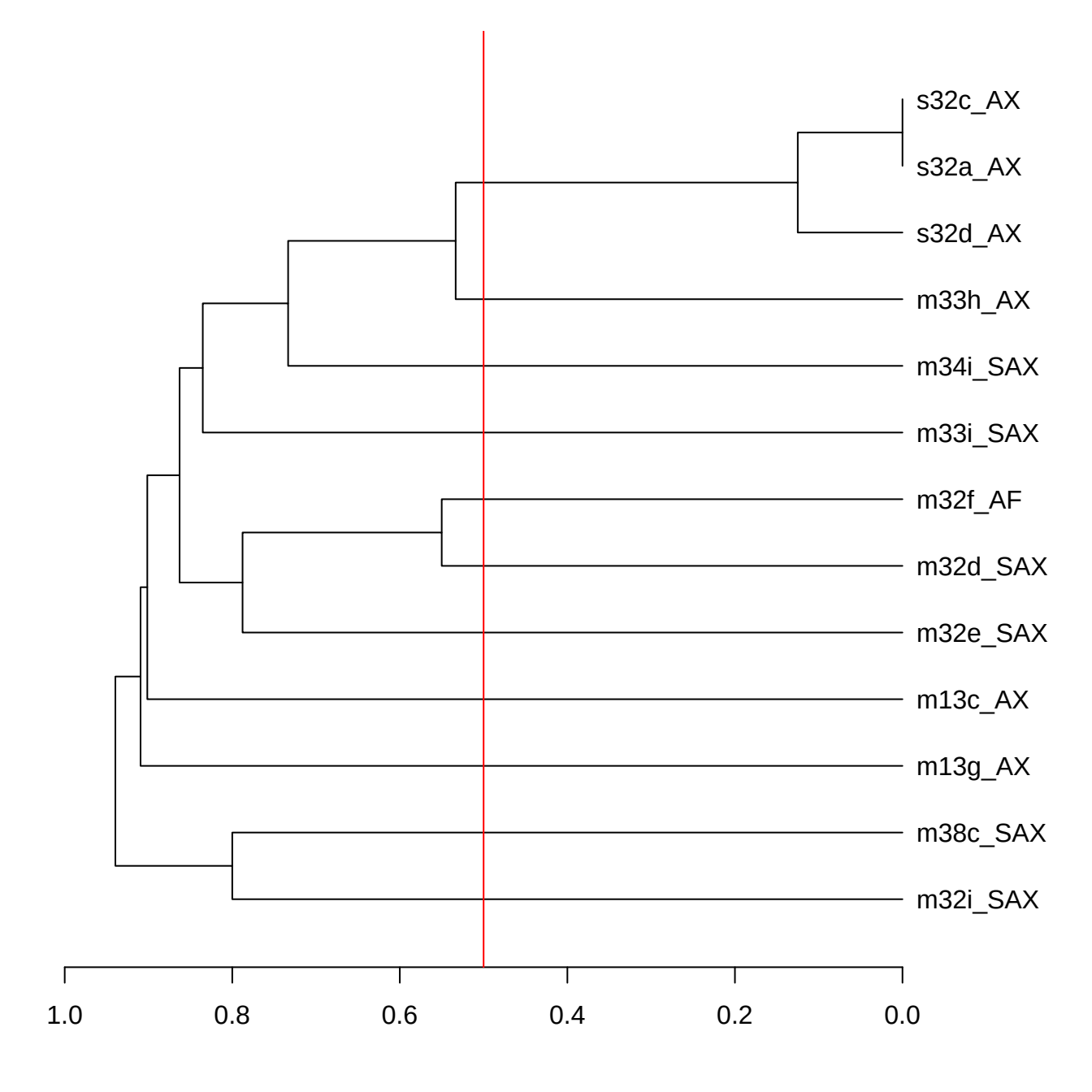
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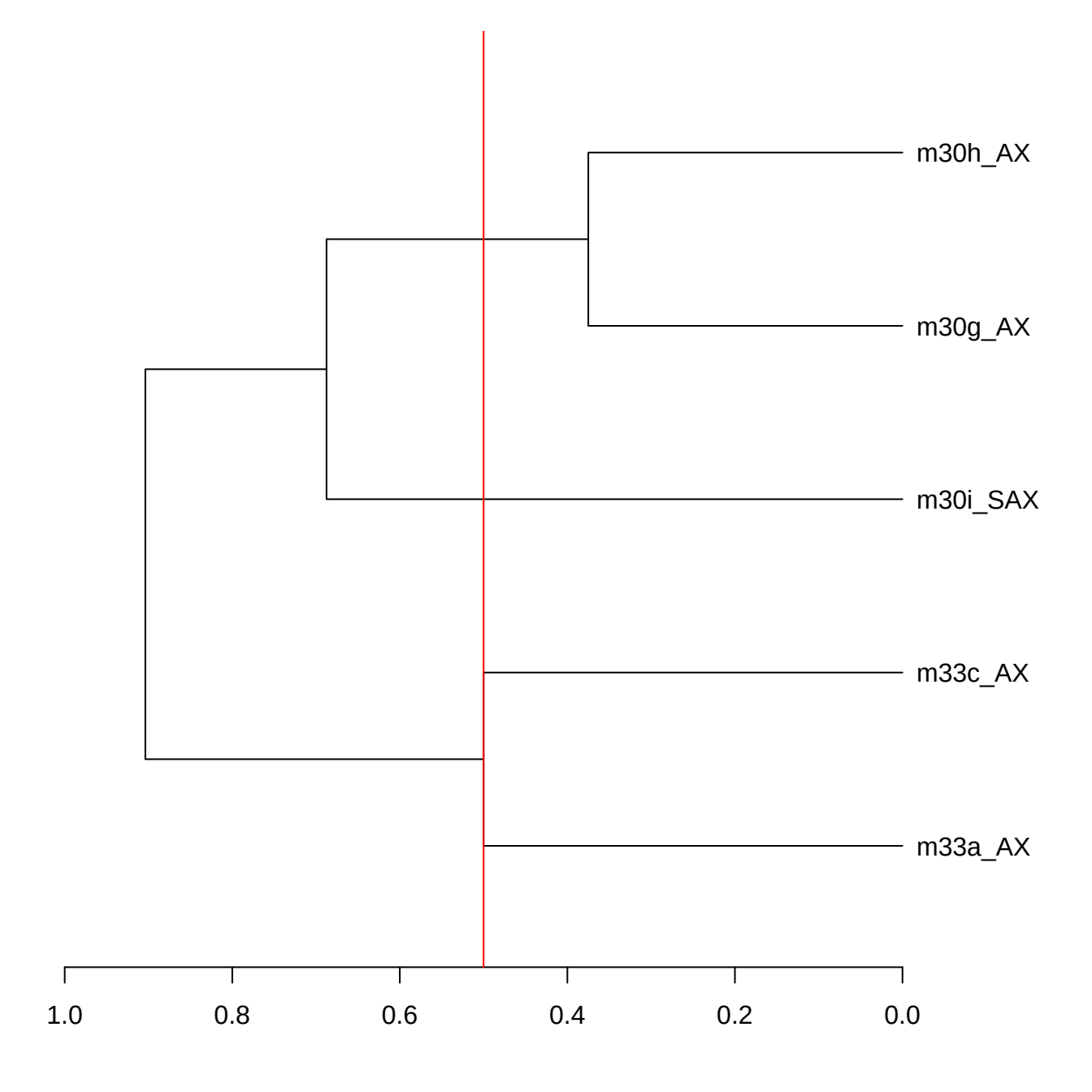
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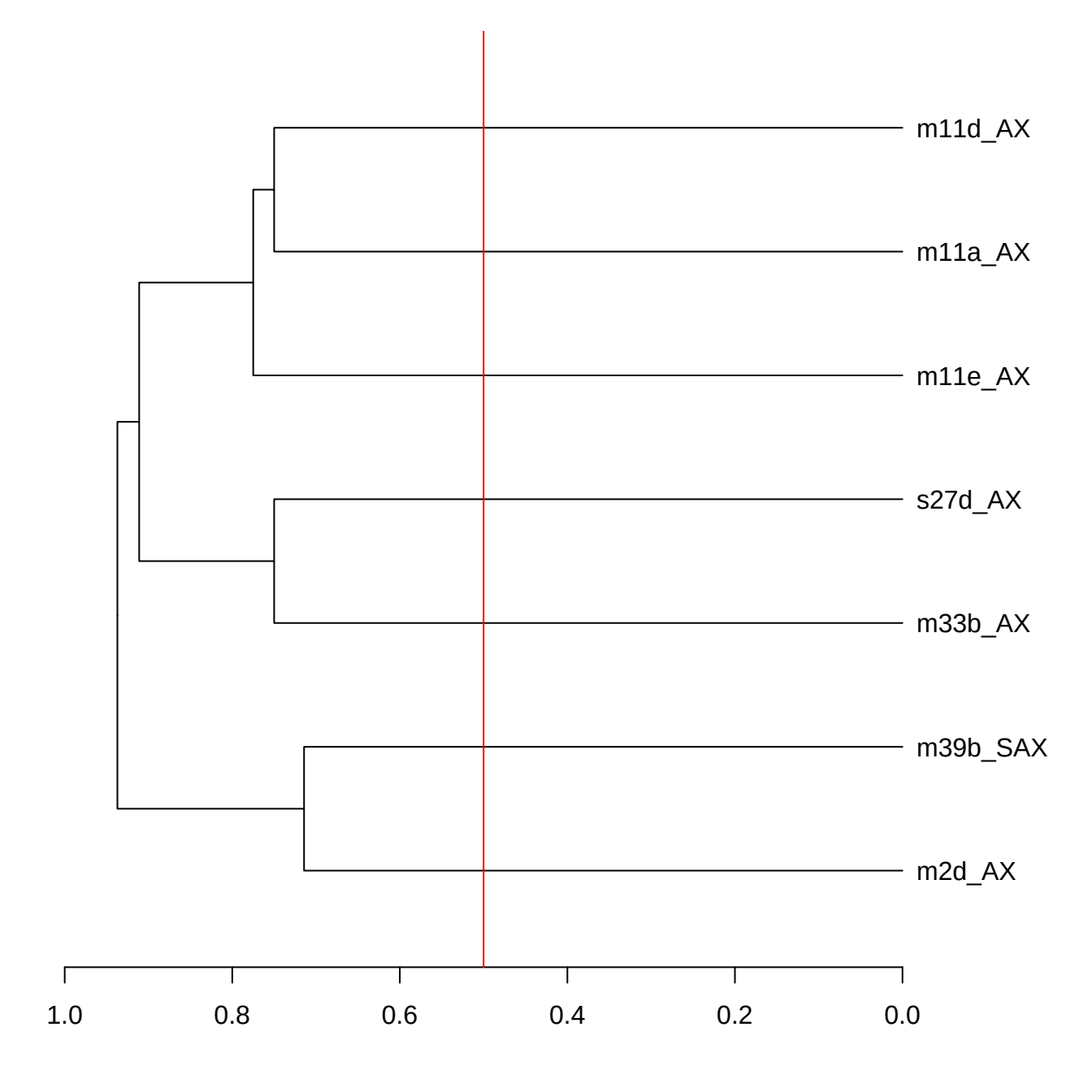
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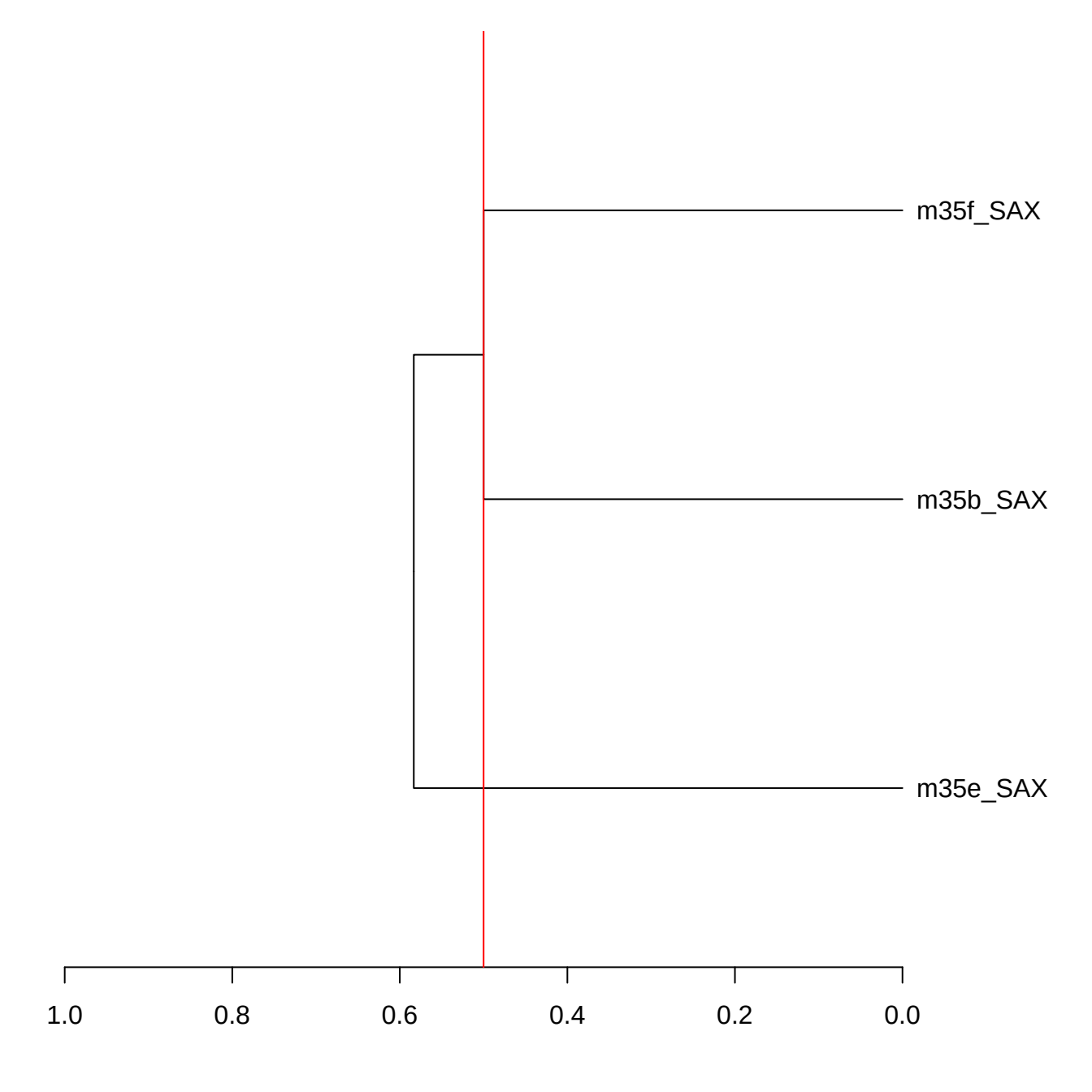
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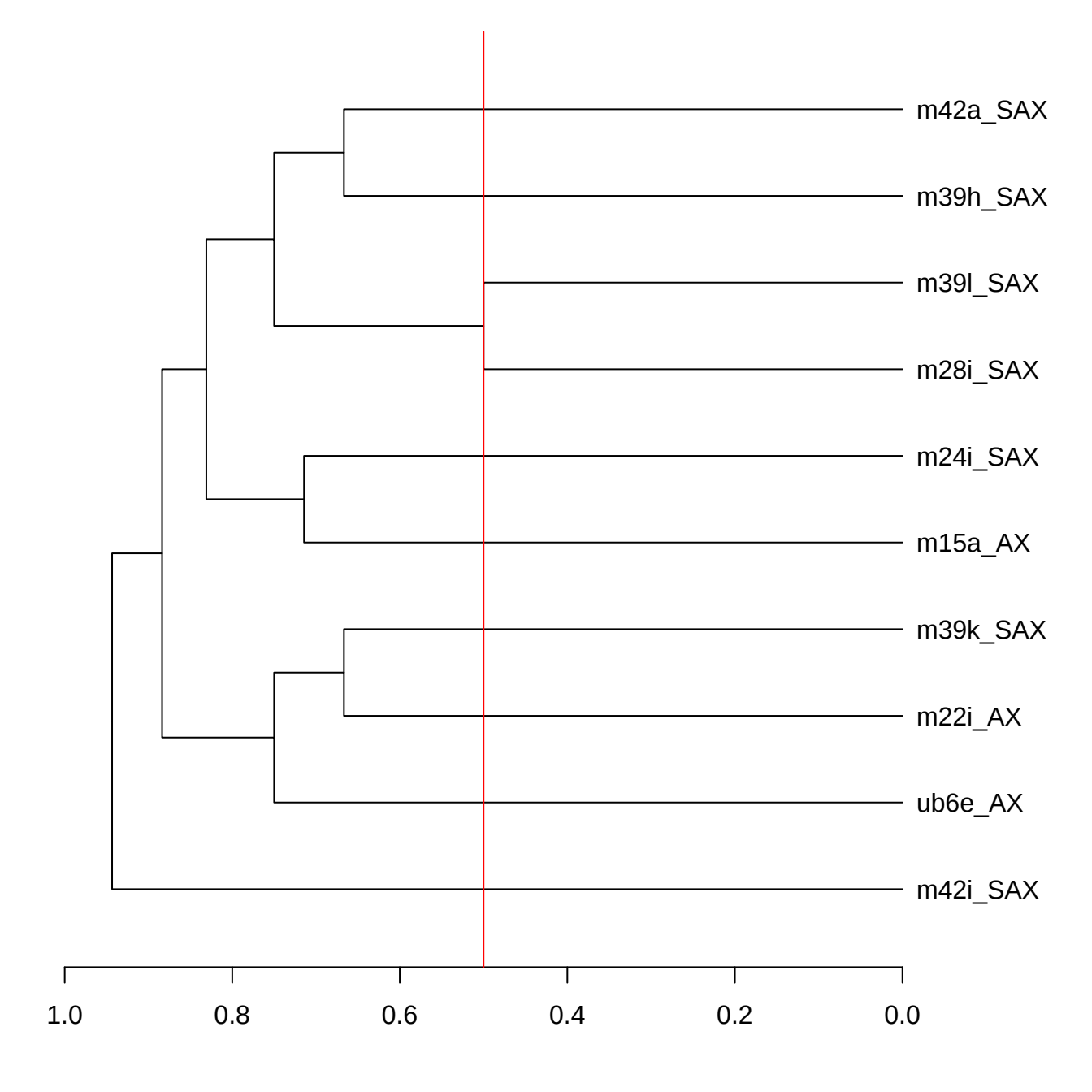
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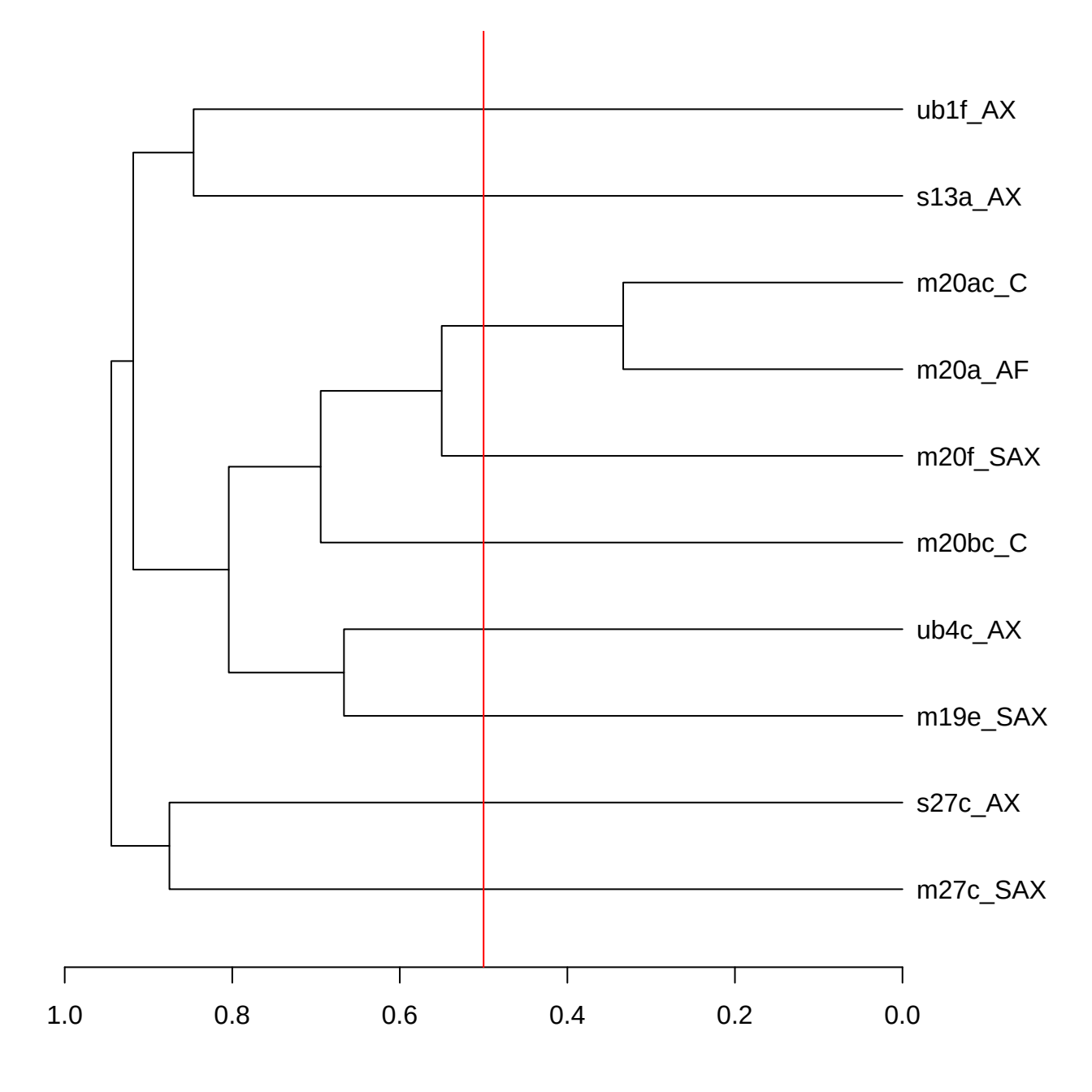
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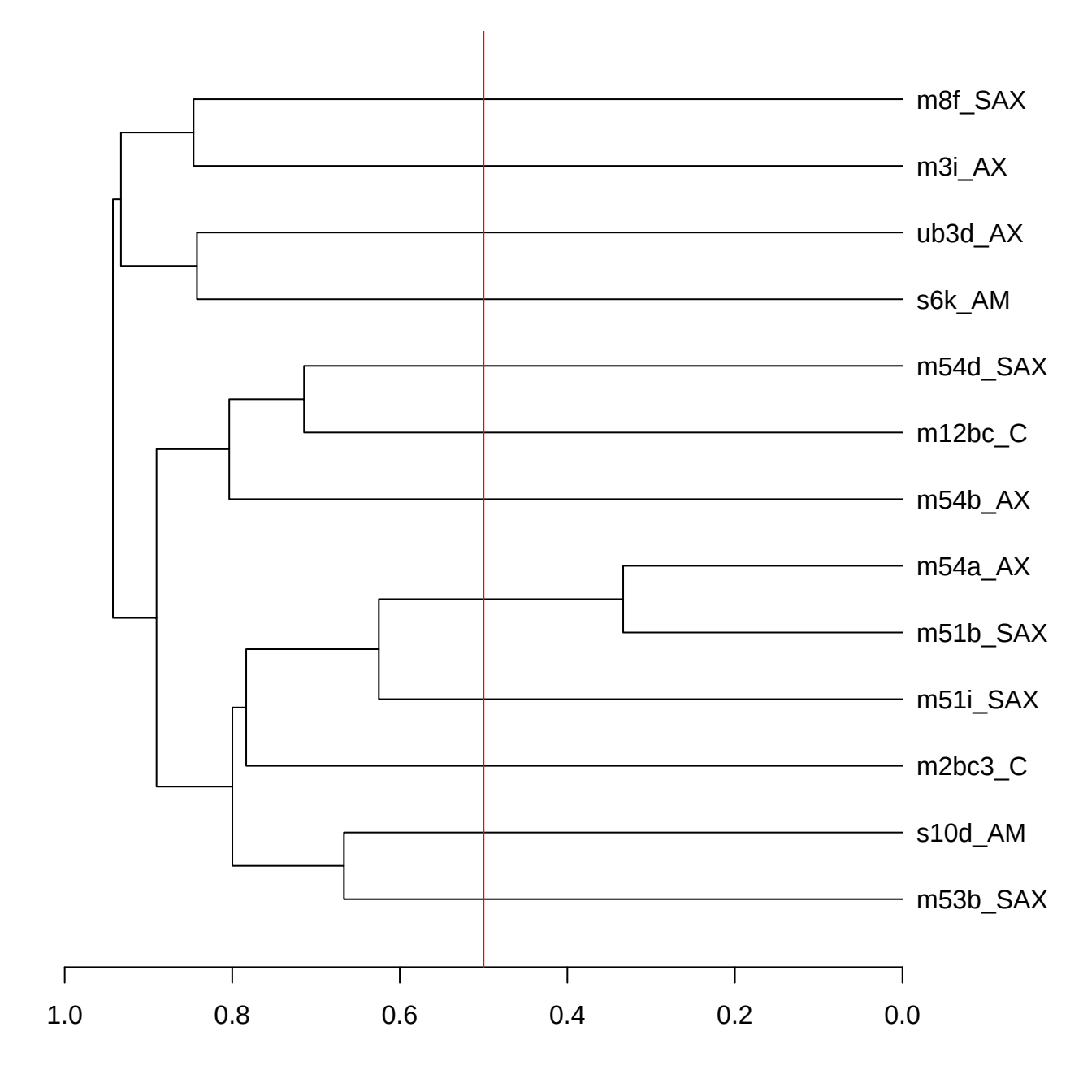
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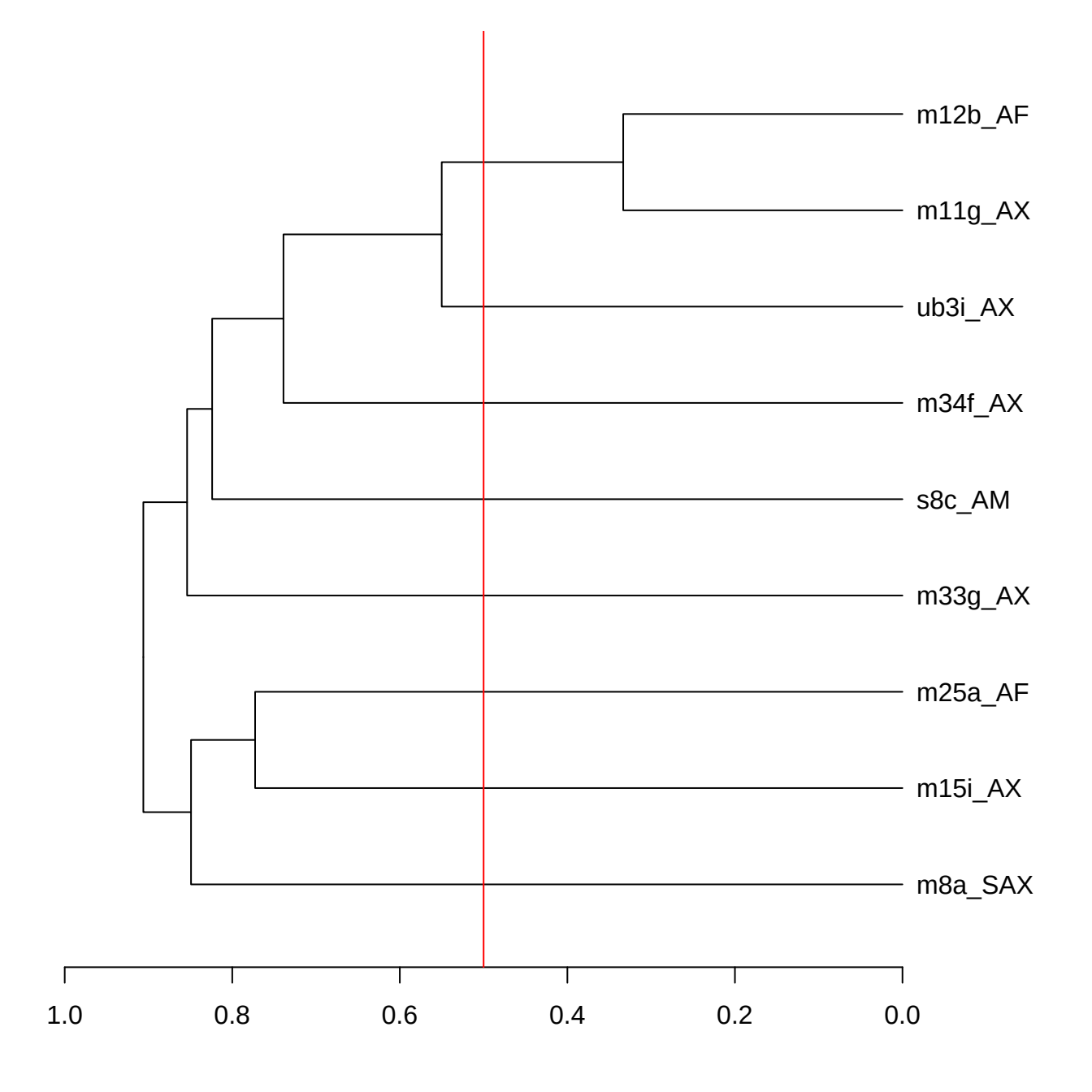
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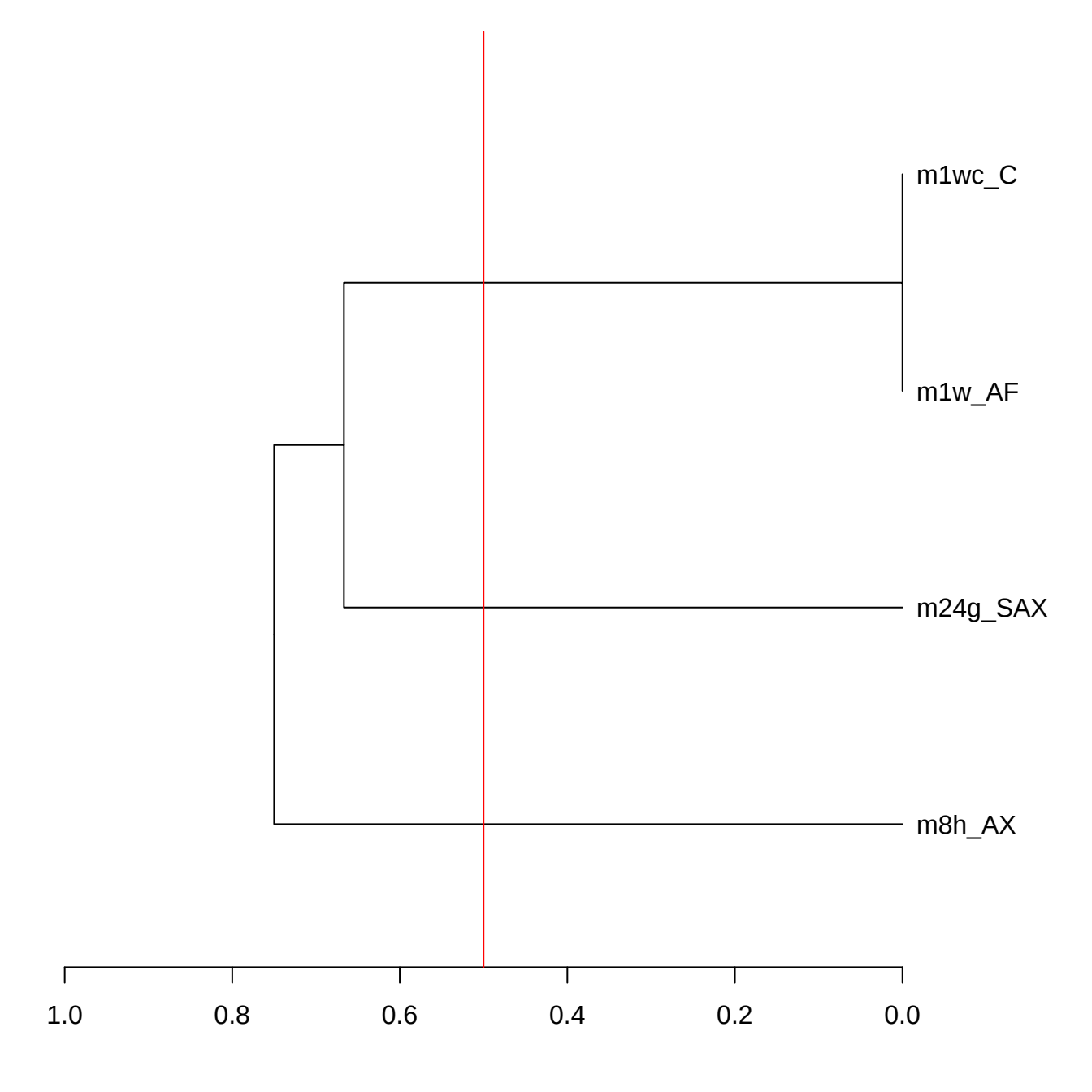
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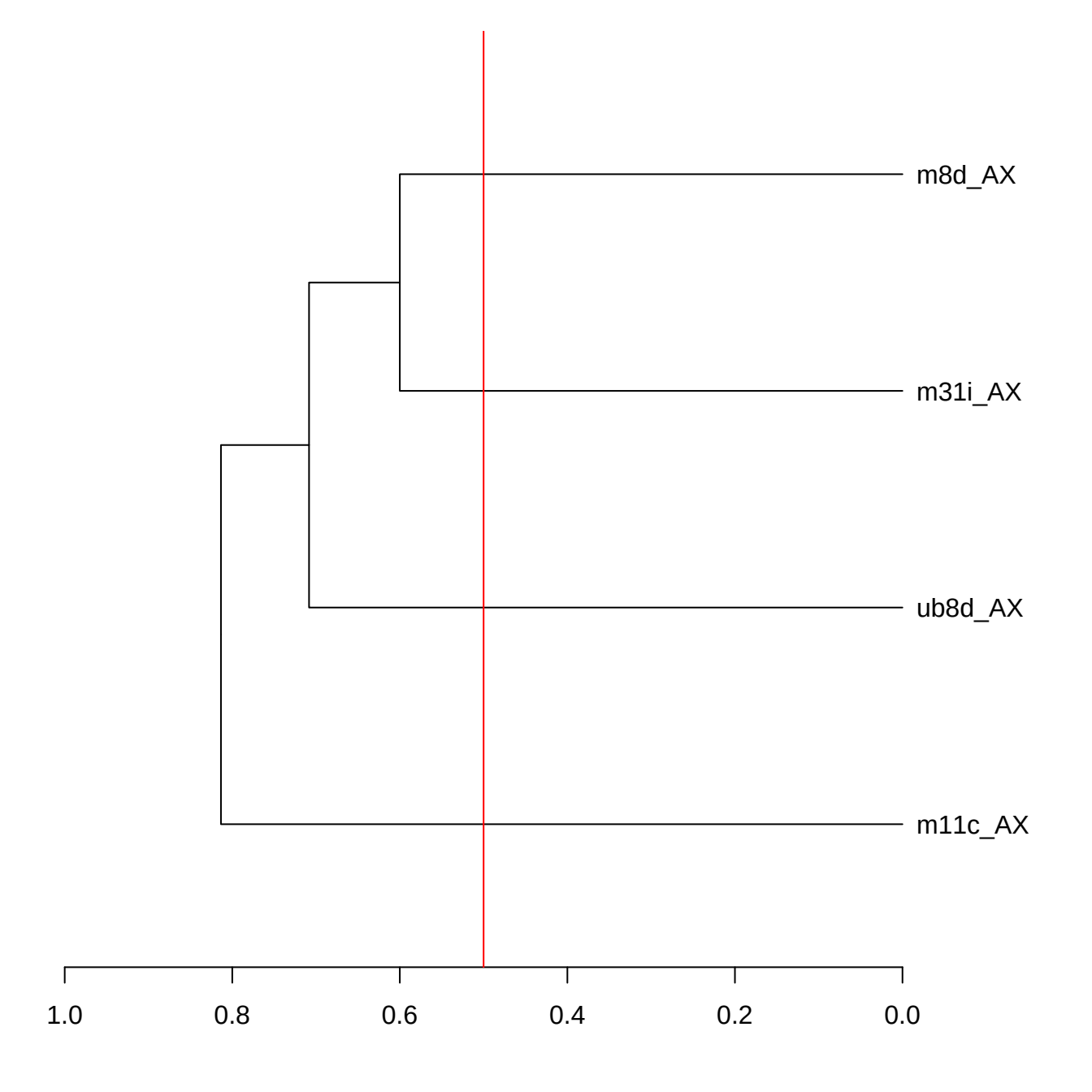
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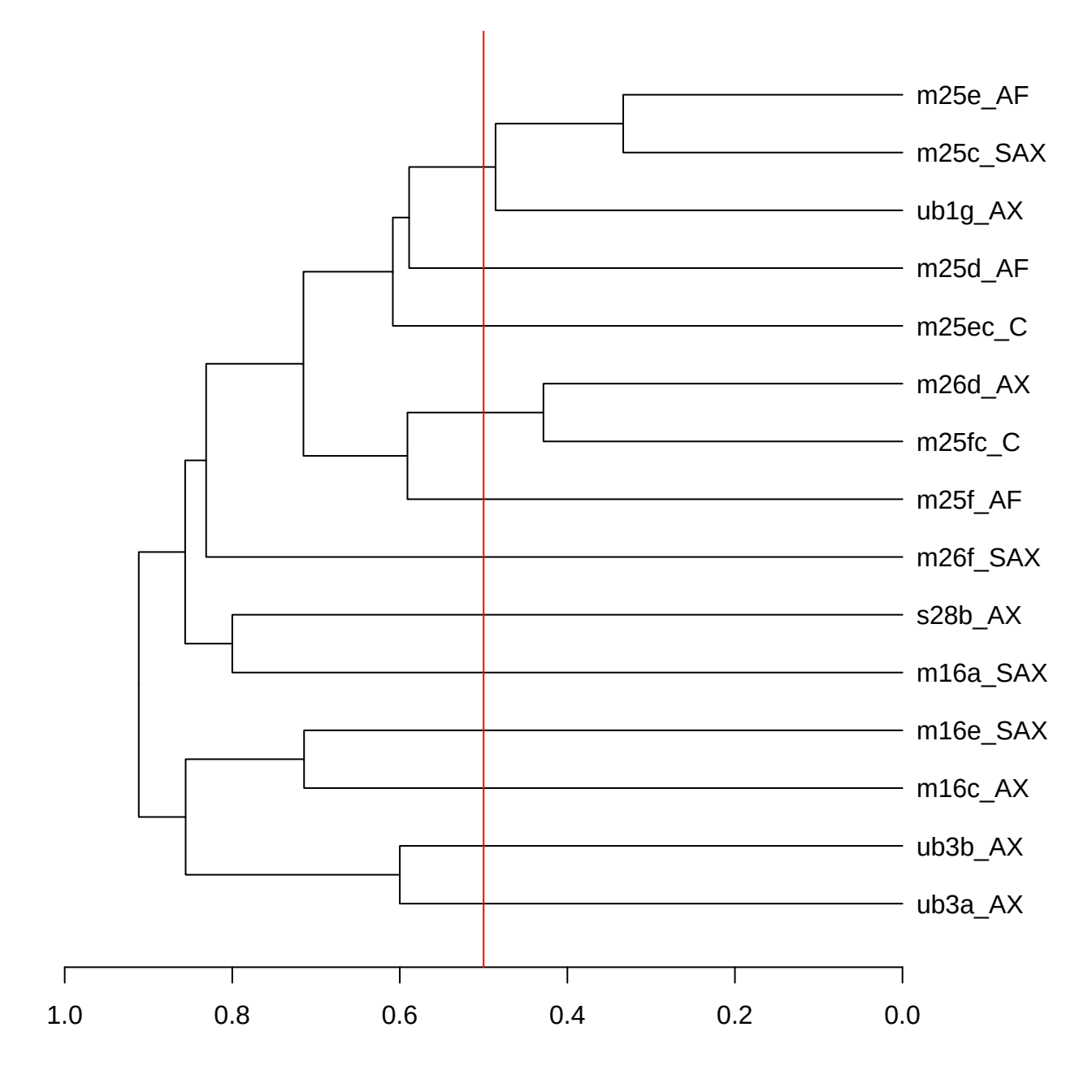
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m25f_AF
m26f_SAX
s28b_AX
m16a_SAX
m16e_SAX
m16c_AX
ub3b_AX
ub3a_AX
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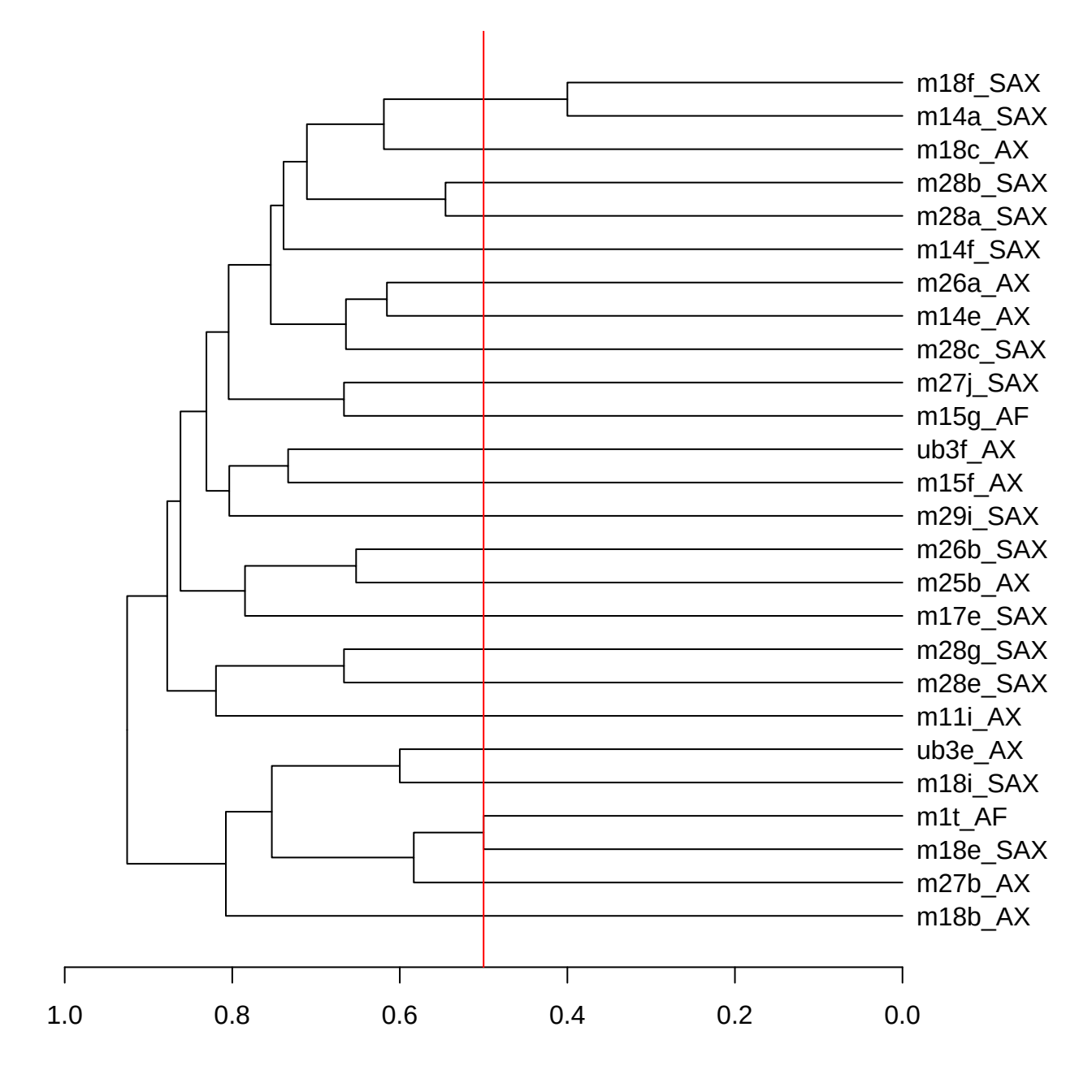
0.8
0.6
0.4
0.2
0.0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m18c_AX
m28b_SAX
m28a_SAX
m14f_SAX
m26a_AX
m14e_AX
m28c_SAX
m27j_SAX
m15g_AF
ub3f_AX
m15f_AX
m29i_SAX
m26b_SAX
m25b_AX
m17e_SAX
m28g_SAX
m28e_SAX
m11i_AX
ub3e_AX
m18i_SAX
m1t_AF
m18e_SAX
m27b_AX
m18b_AX
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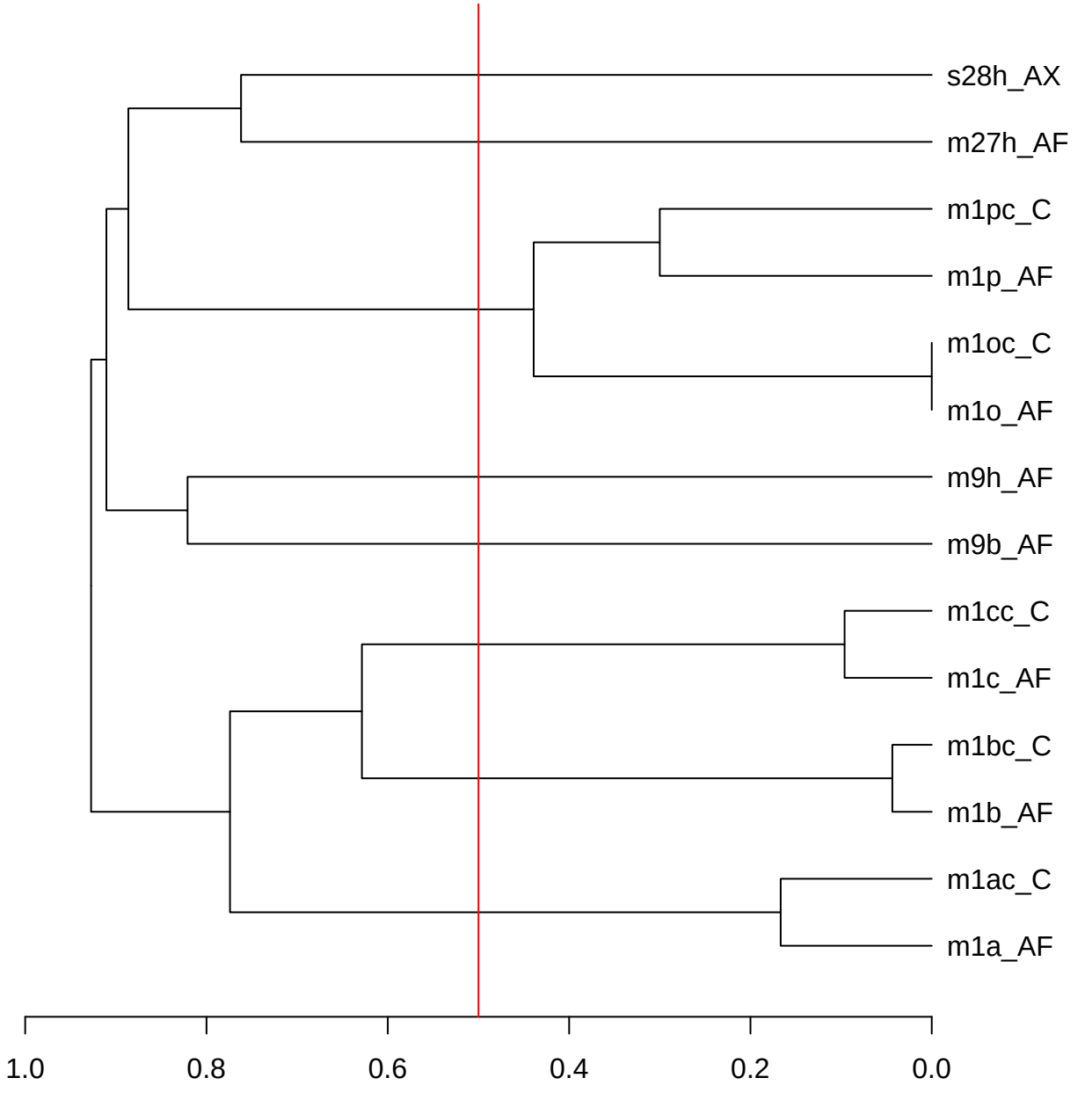
0.4
0.2
0.0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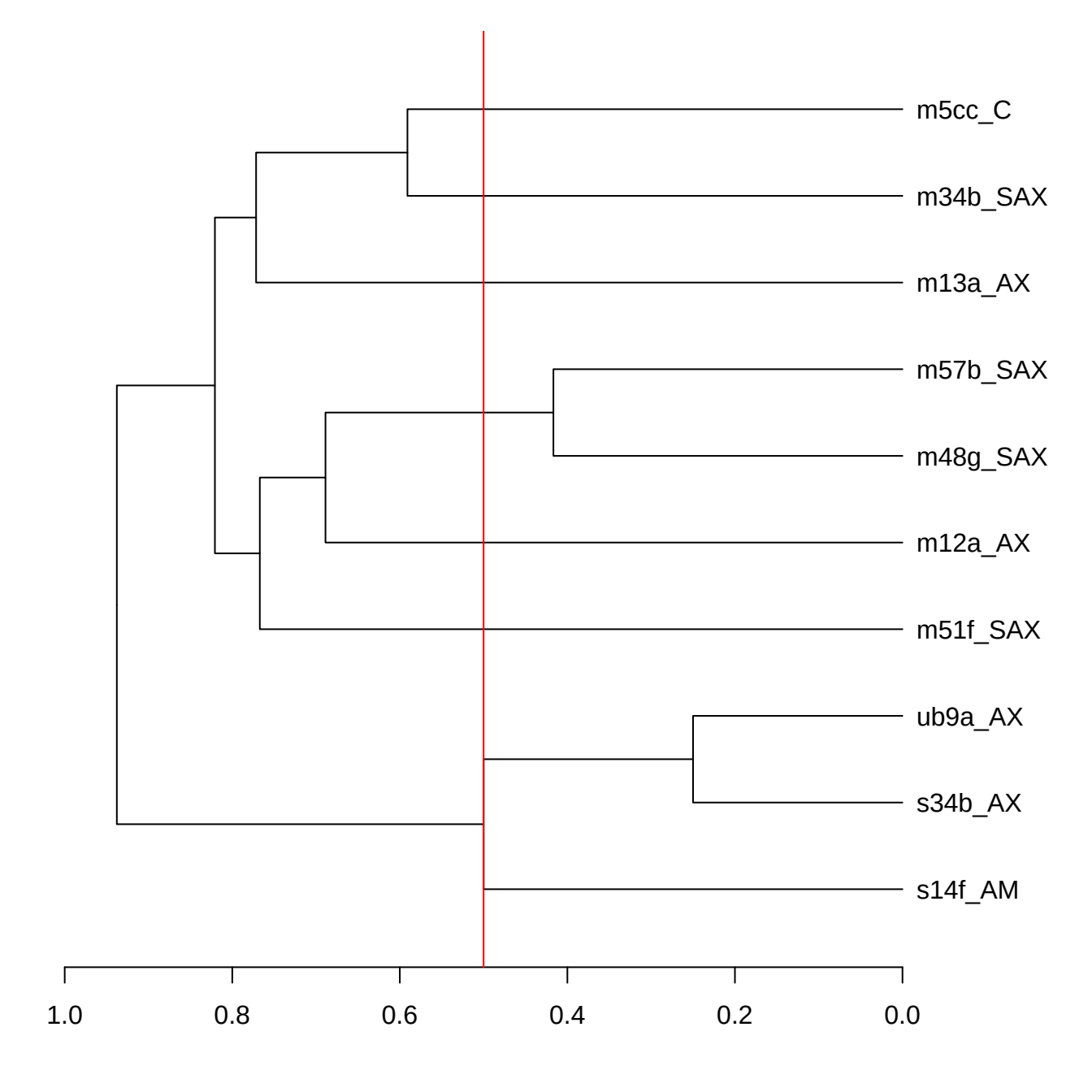
m27h_AF
m1pc_C
m1p_AF
m1oc_C
m1o_AF
m9h_AF
m9b_AF
m1cc_C
m1c_AF
m1bc_C
m1b_AF
m1ac_C
m1a_AF
1.0
0.8
0.6
0.4
0.2
0.0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m34b_SAX
m13a_AX
m57b_SAX
m48g_SAX
m12a_AX
m51f_SAX
ub9a_AX
s34b_AX
s14f_AM
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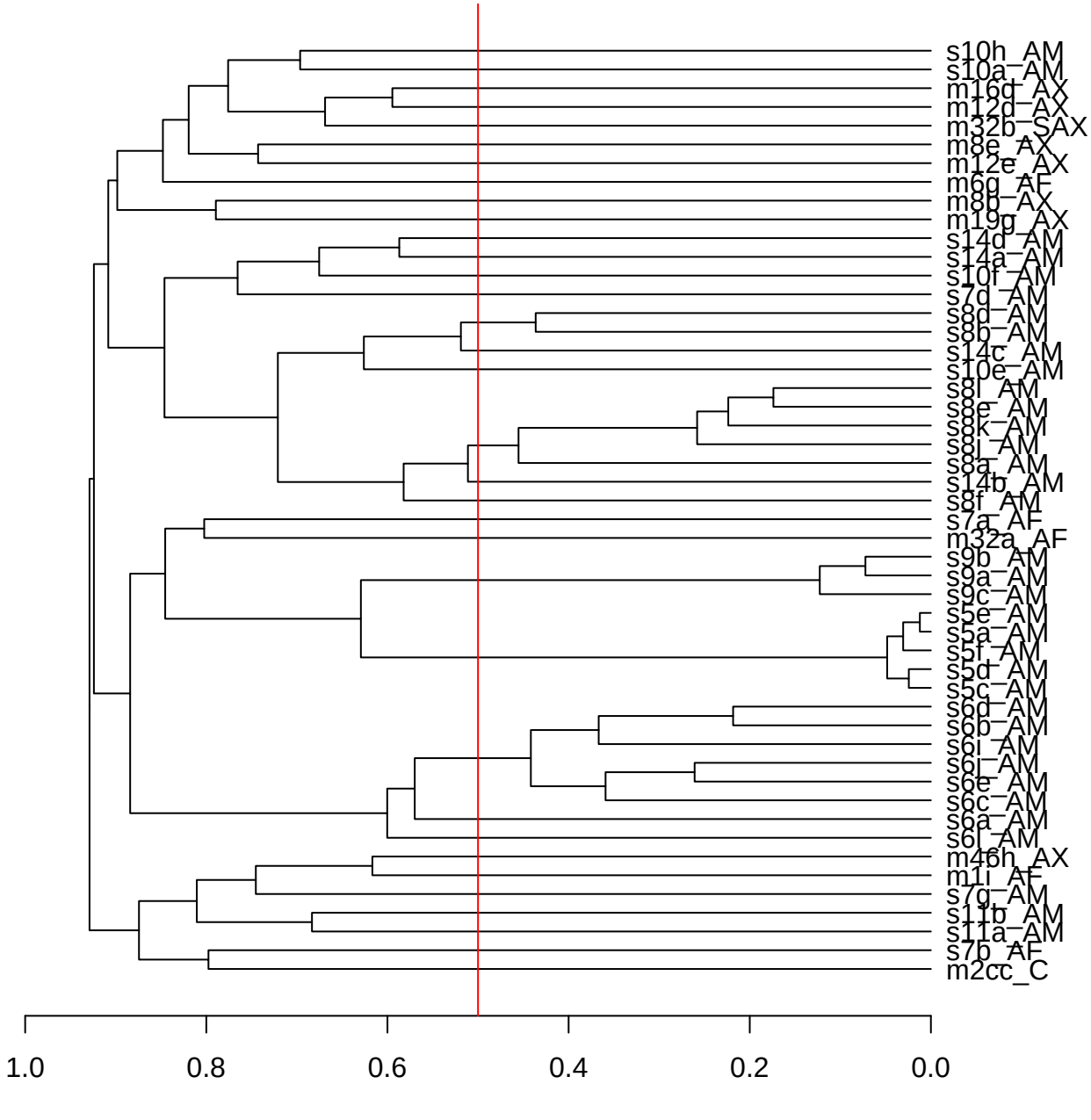
0.2
0.0


s10h_AM
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m32b_SAX
m8e_AX
m12e_AX
m6g_AF
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m19g_AX
s14d_AM
s14a_AM
s10f_AM
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s8d_AM
s8b_AM
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s8k_AM
s8j_AM
s8a_AM
s14b_AM
s8f_AM
s7a_AF
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s9a_AM
s9c_AM
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s5d_AM
s5c_AM
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s6i_AM
s6j_AM
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s6c_AM
s6a_AM
s6l_AM
m46h_AX
m1i_AF
s7g_AM
s11b_AM
s11a_AM
s7b_AF
m2cc_C
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0.8
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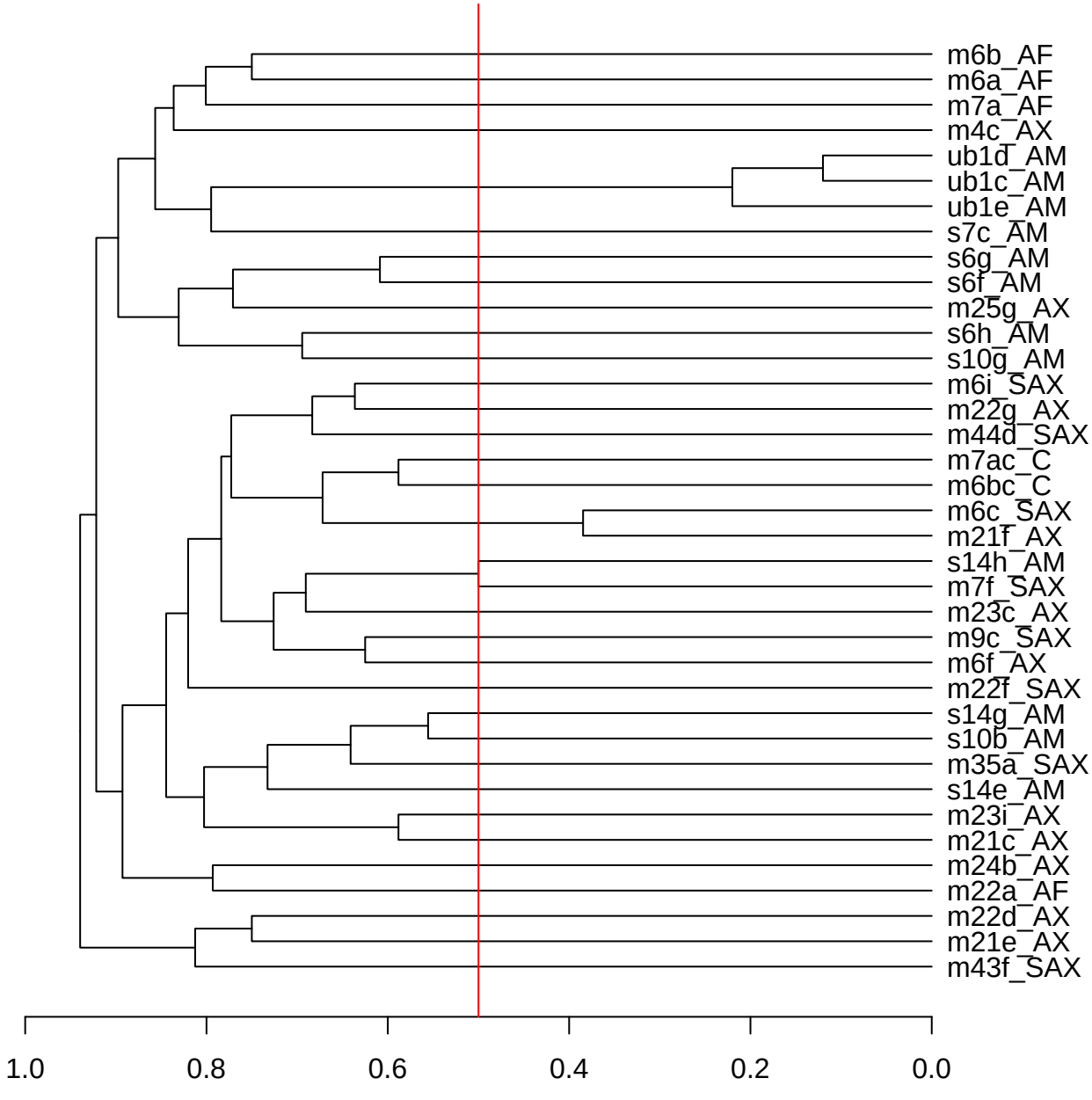
0.4
0.2
0.0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m6a_AF
m7a_AF
m4c_AX
ub1d_AM
ub1c_AM
ub1e_AM
s7c_AM
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s6f_AM
m25g_AX
s6h_AM
s10g_AM
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m22g_AX
m44d_SAX
m7ac_C
m6bc_C
m6c_SAX
m21f_AX
s14h_AM
m7f_SAX
m23c_AX
m9c_SAX
m6f_AX
m22f_SAX
s14g_AM
s10b_AM
m35a_SAX
s14e_AM
m23i_AX
m21c_AX
m24b_AX
m22a_AF
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m21e_AX
m43f_SAX
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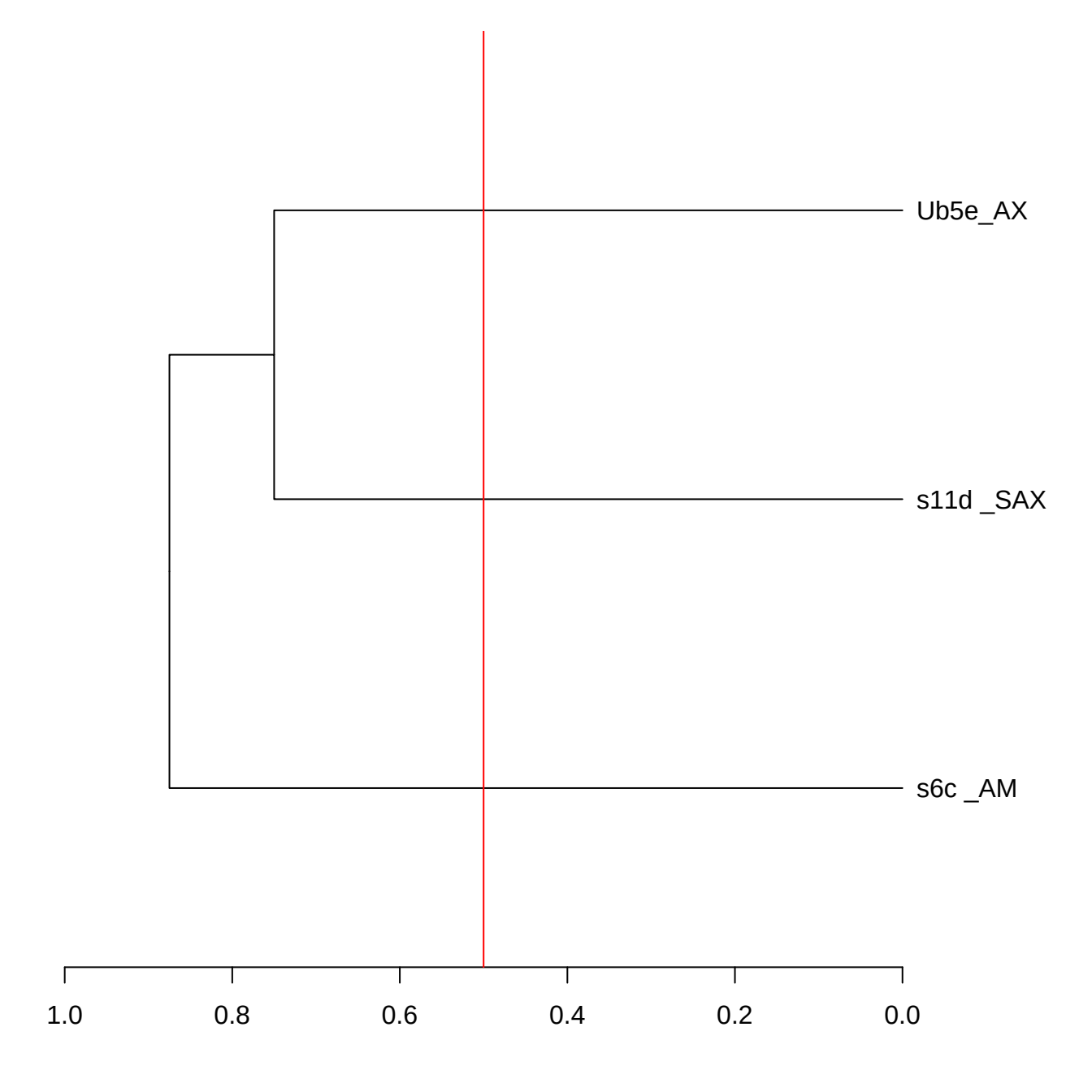
0.8
0.6
0.4
0.2
0.0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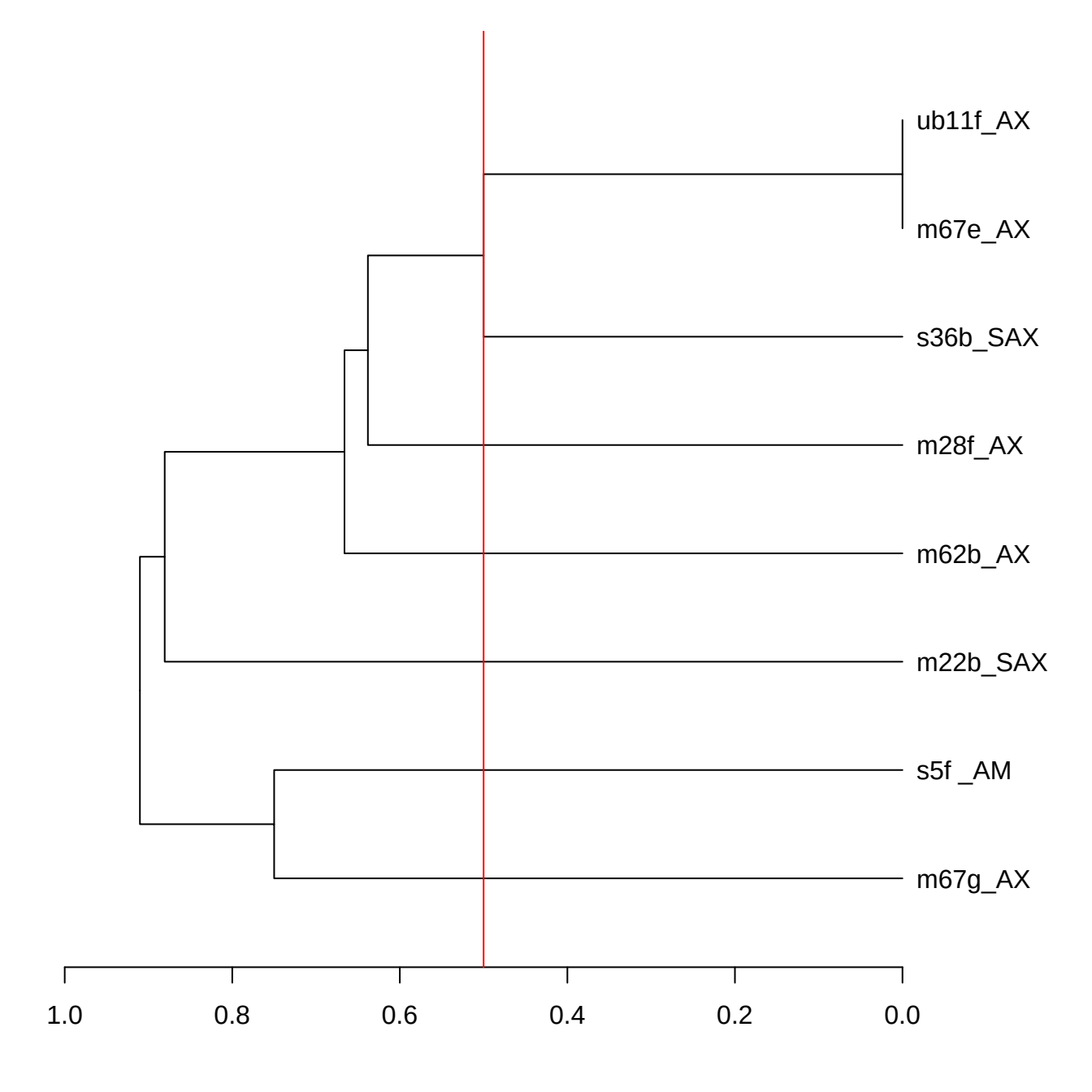
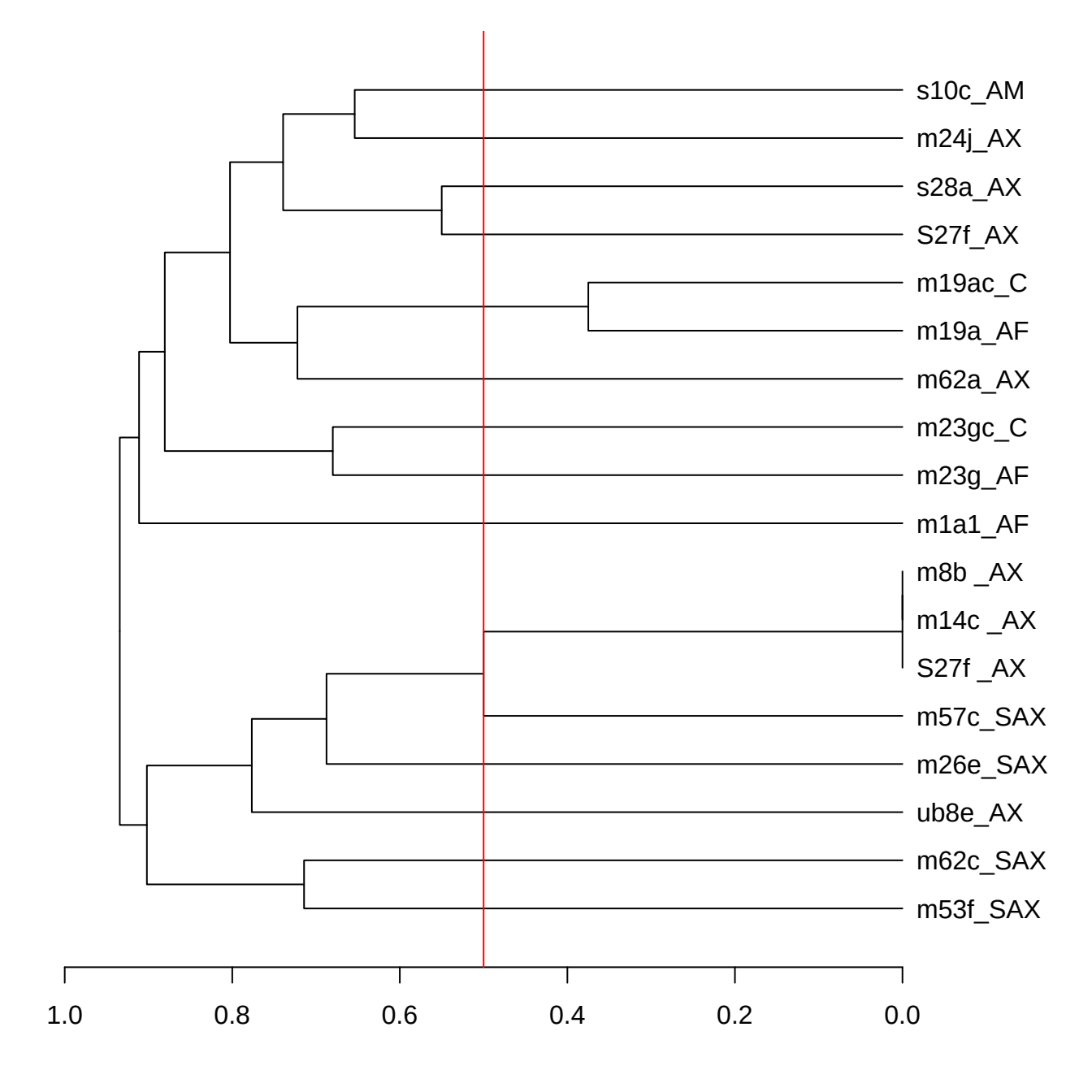
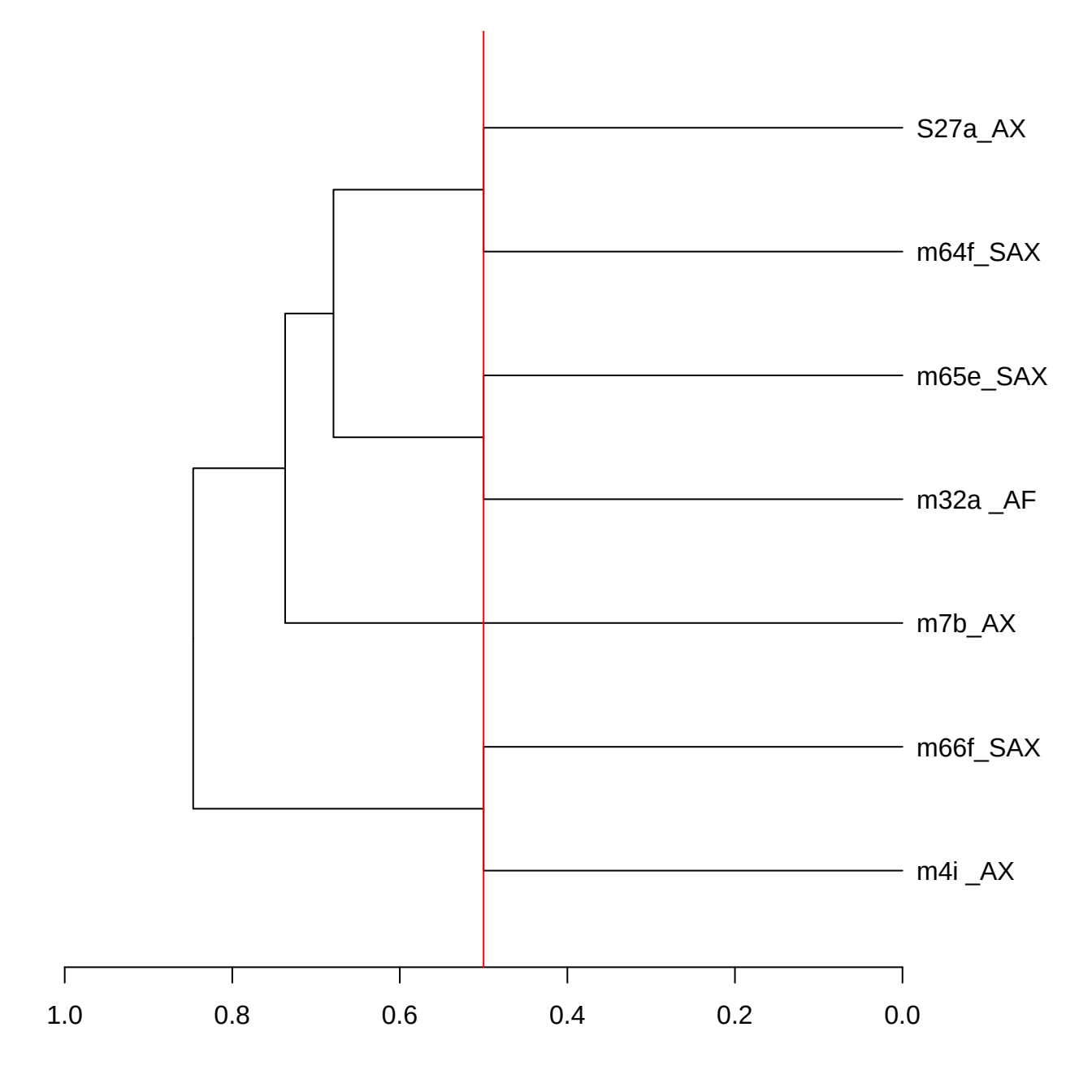
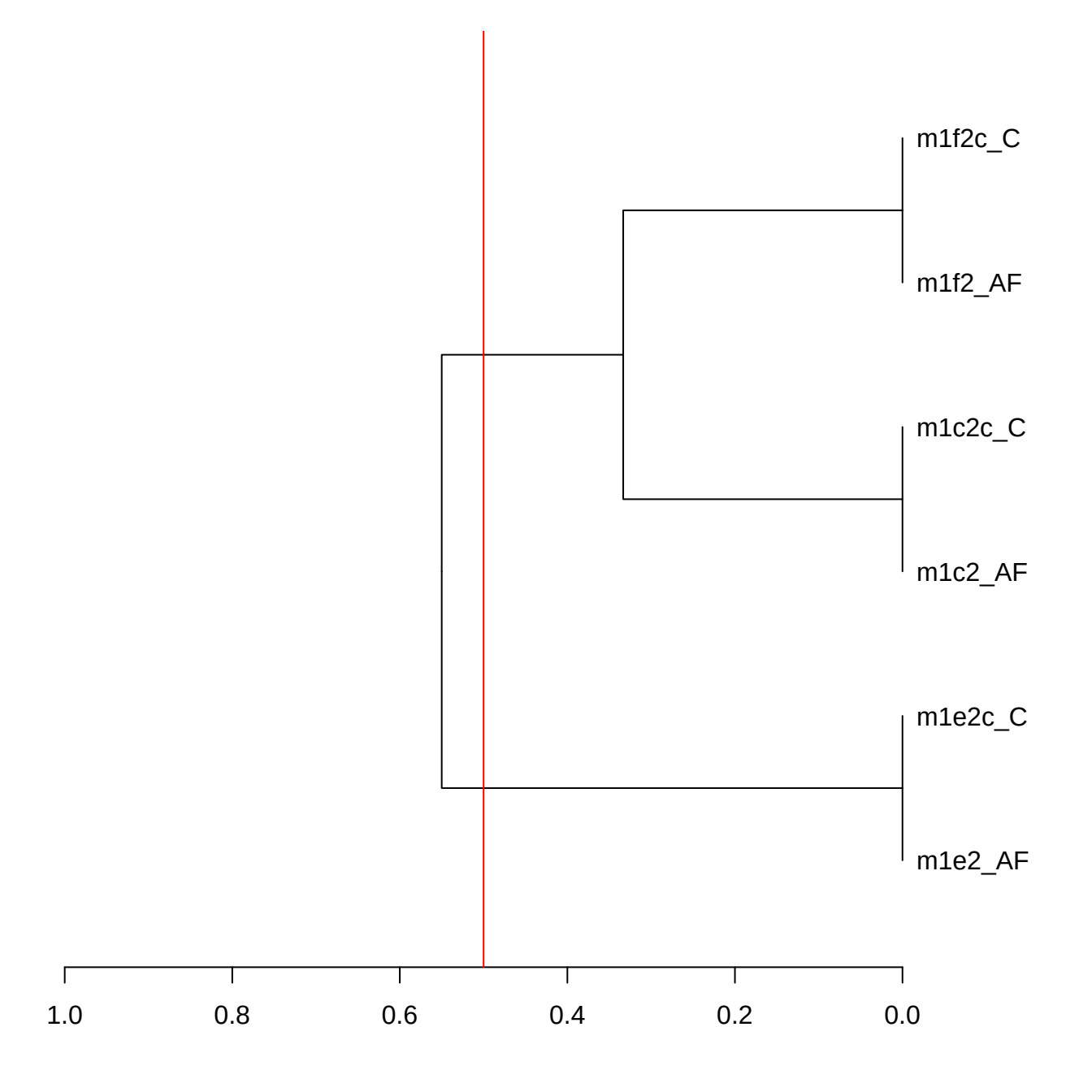
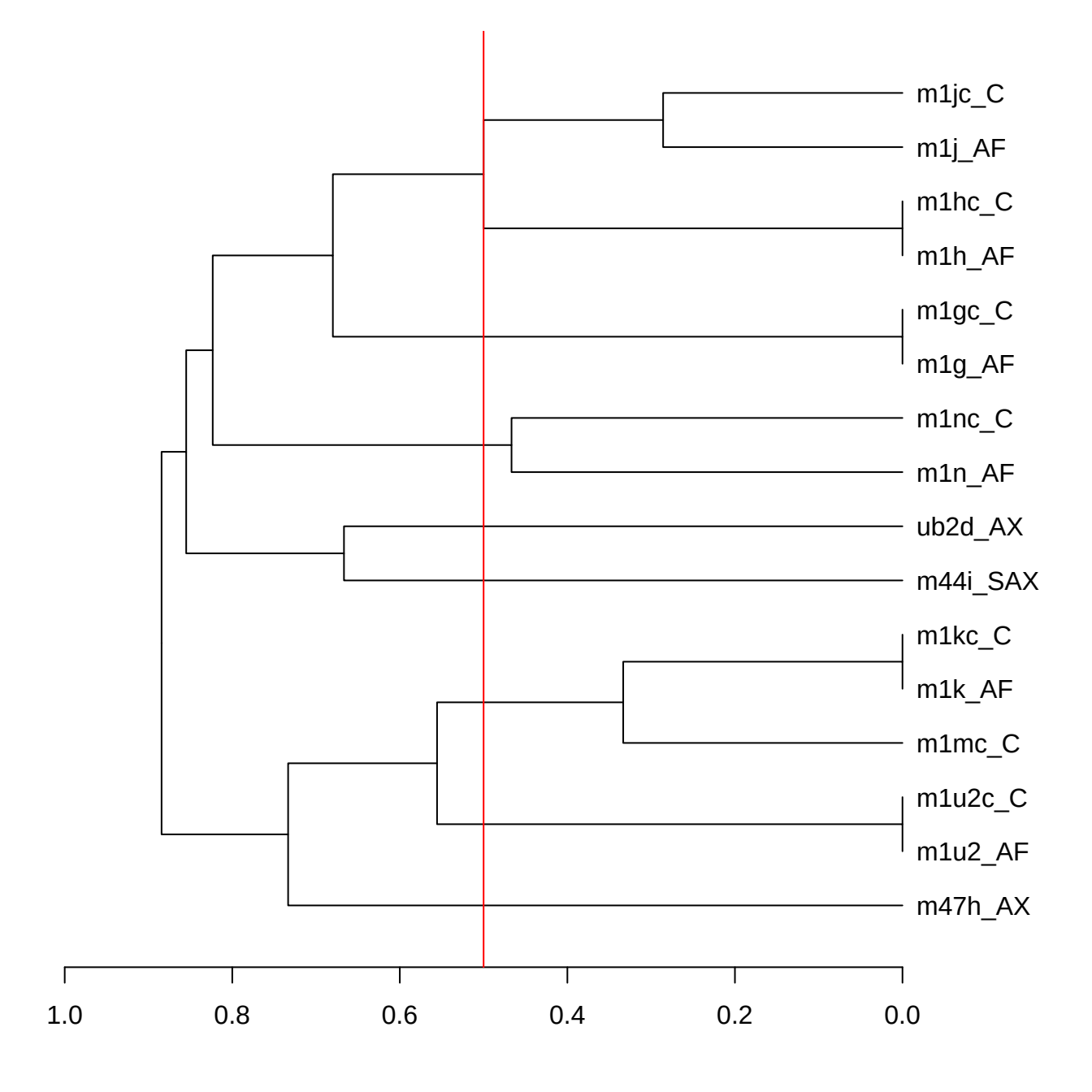
s11d _SAX
s6c _AM
1.0
0.8
0.6
0.4
0.2
0.0

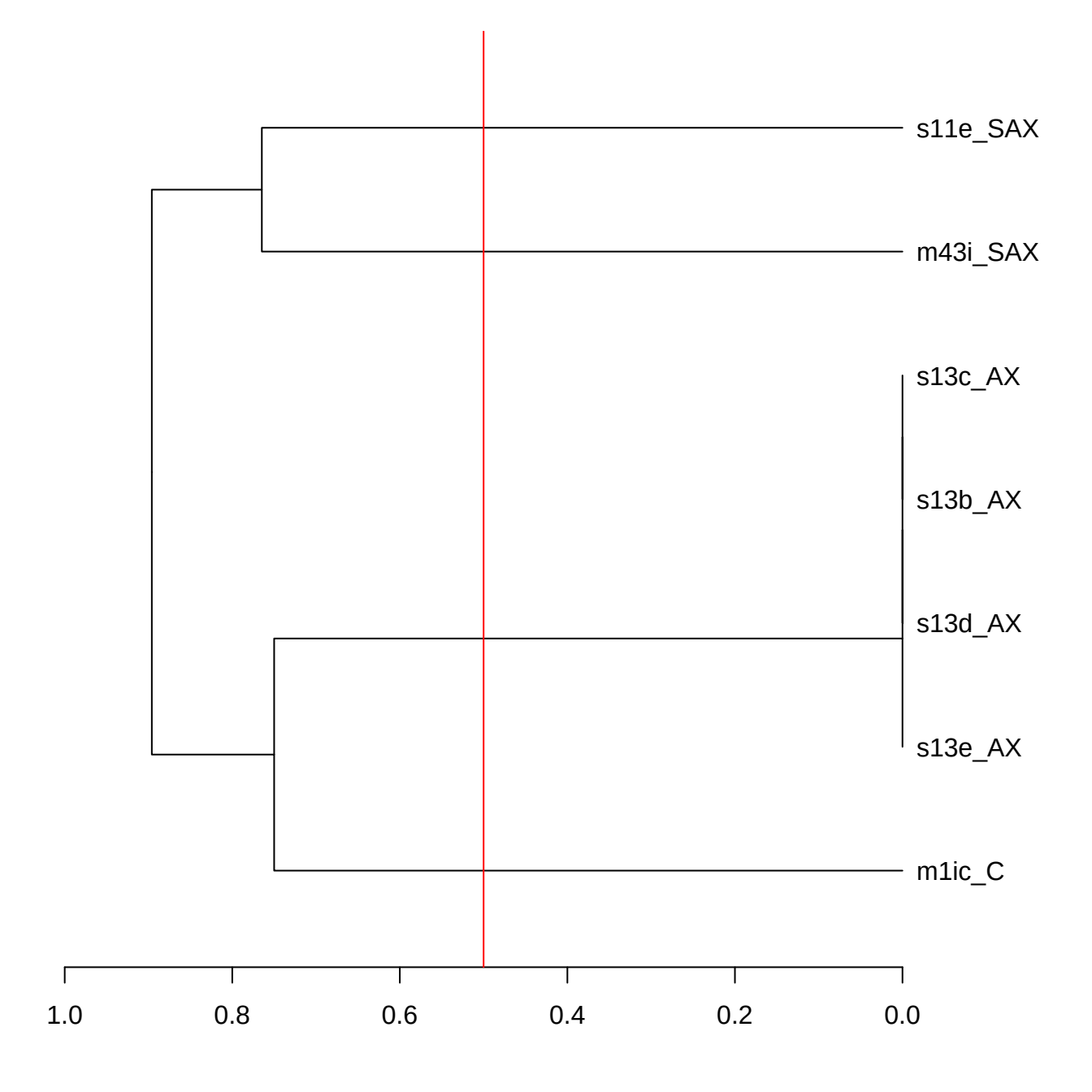

ub11f_AX
m67e_AX
s36b_SAX
m28f_AX
m62b_AX
m22b_SAX
s5f _AM
m67g_AX
1.0
0.8
0.6
0.4
0.2
0.0

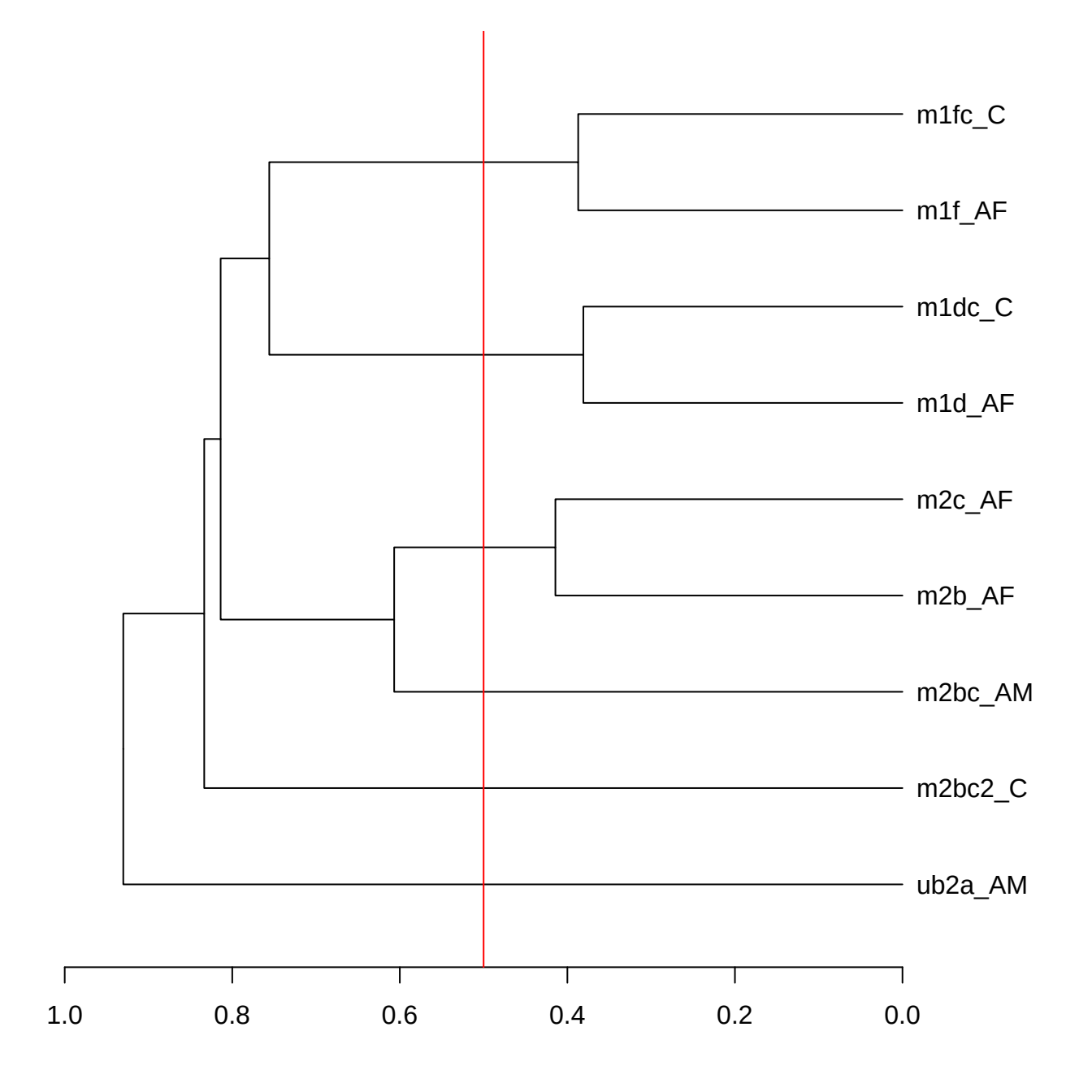

s10c_AM
m24j_AX
s28a_AX
S27f_AX
m19ac_C
m19a_AF
m62a_AX
m23gc_C
m23g_AF
m1a1_AF
m8b _AX
m14c _AX
S27f _AX
m57c_SAX
m26e_SAX
ub8e_AX
m62c_SAX
m53f_SAX
1.0
0.8
0.6
0.4
0.2
0.0


S27a_AX
m64f_SAX
m65e_SAX
m32a _AF
m7b_AX
m66f_SAX
m4i _AX
1.0
0.8
0.6
0.4
0.2
0.0


m1f2c_C
m1f2_AF
m1c2c_C
m1c2_AF
m1e2c_C
m1e2_AF
1.0
0.8
0.6
0.4
0.2
0.0


m1jc_C
m1j_AF
m1hc_C
m1h_AF
m1gc_C
m1g_AF
m1nc_C
m1n_AF
ub2d_AX
m44i_SAX
m1kc_C
m1k_AF
m1mc_C
m1u2c_C
m1u2_AF
m47h_AX
1.0
0.8
0.6
0.4
0.2
0.0

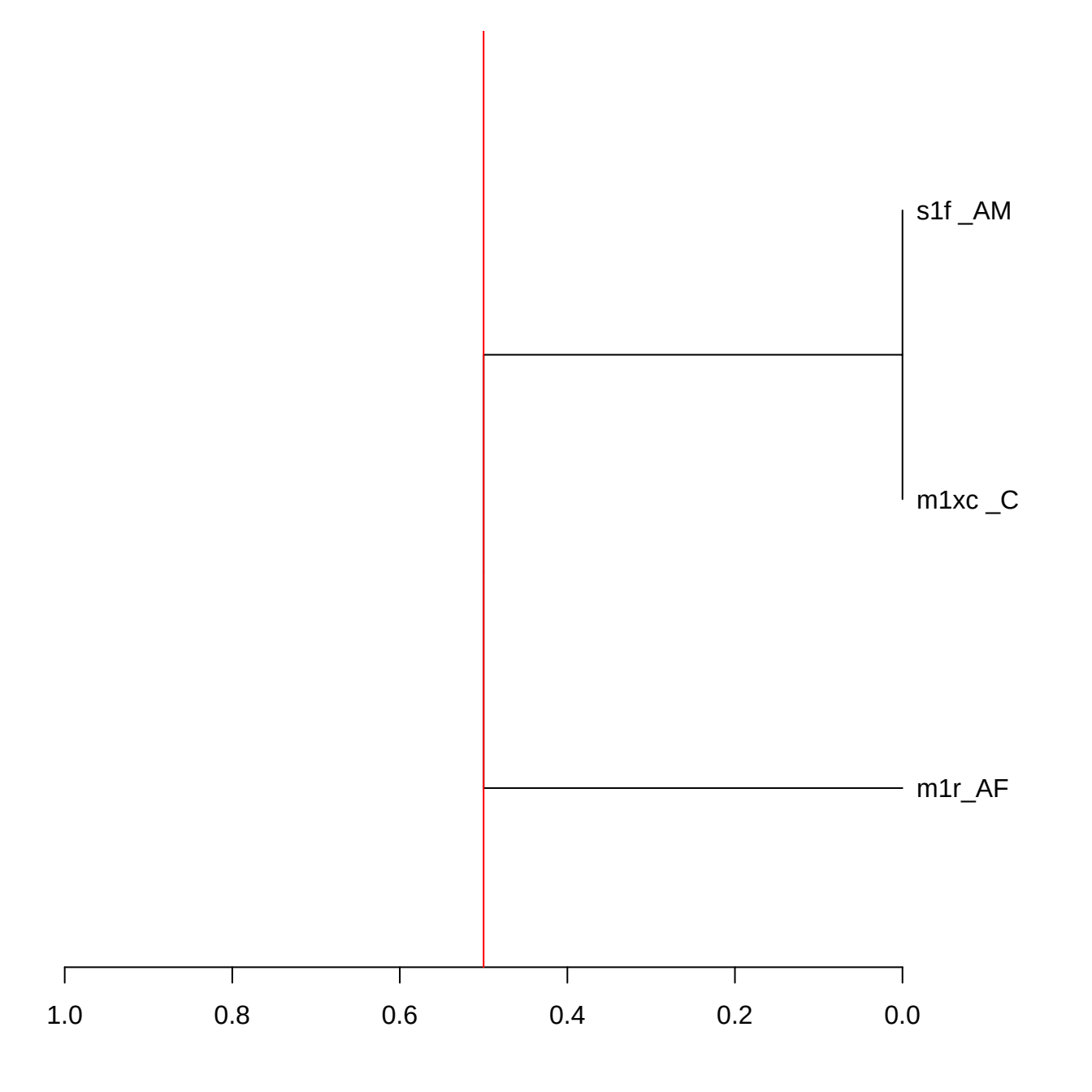

s11e_SAX
m43i_SAX
s13c_AX
s13b_AX
s13d_AX
s13e_AX
m1ic_C
1.0
0.8
0.6
0.4
0.2
0.0

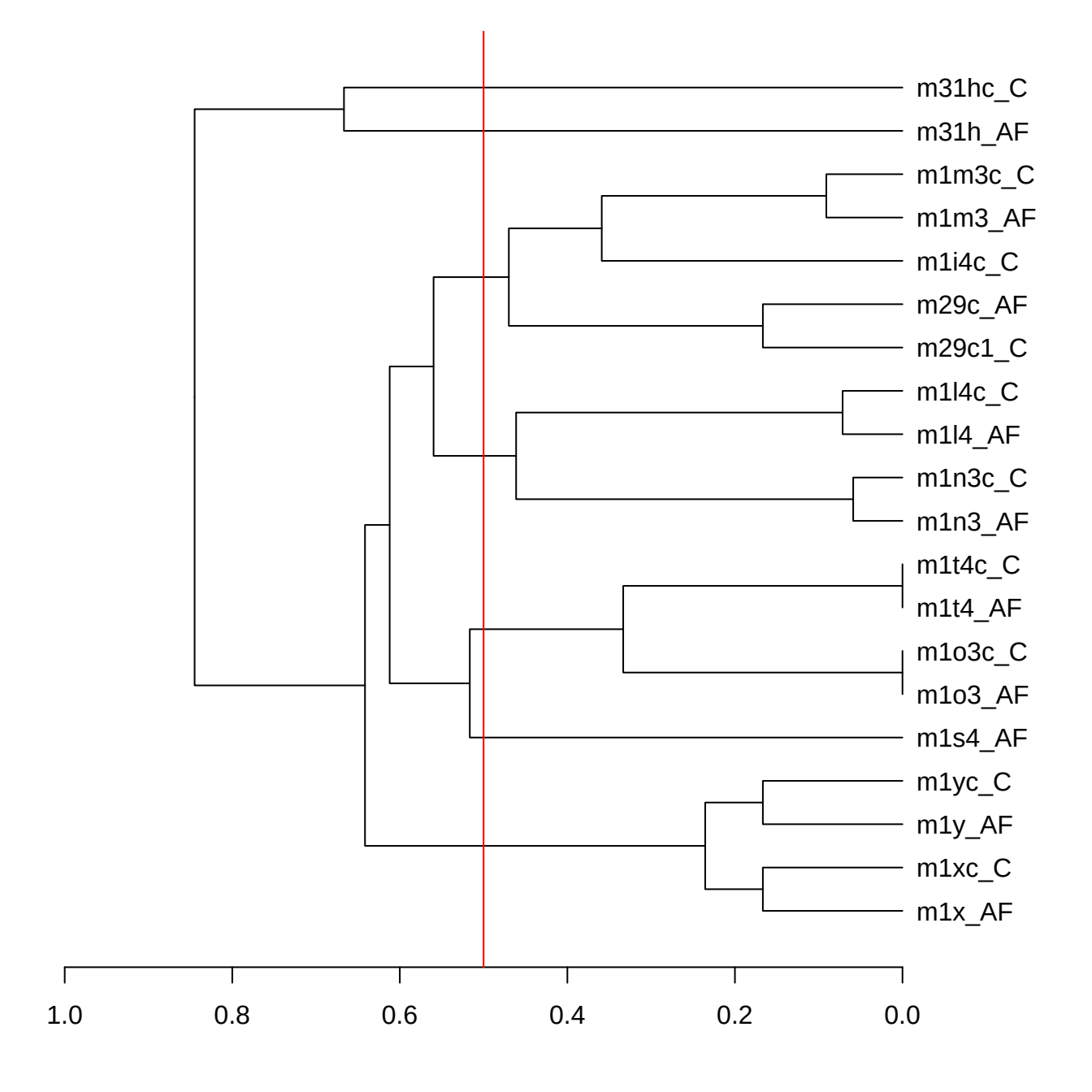

m1fc_C
m1f_AF
m1dc_C
m1d_AF
m2c_AF
m2b_AF
m2bc_AM
m2bc2_C
ub2a_AM
1.0
0.8
0.6
0.4
0.2
0.0

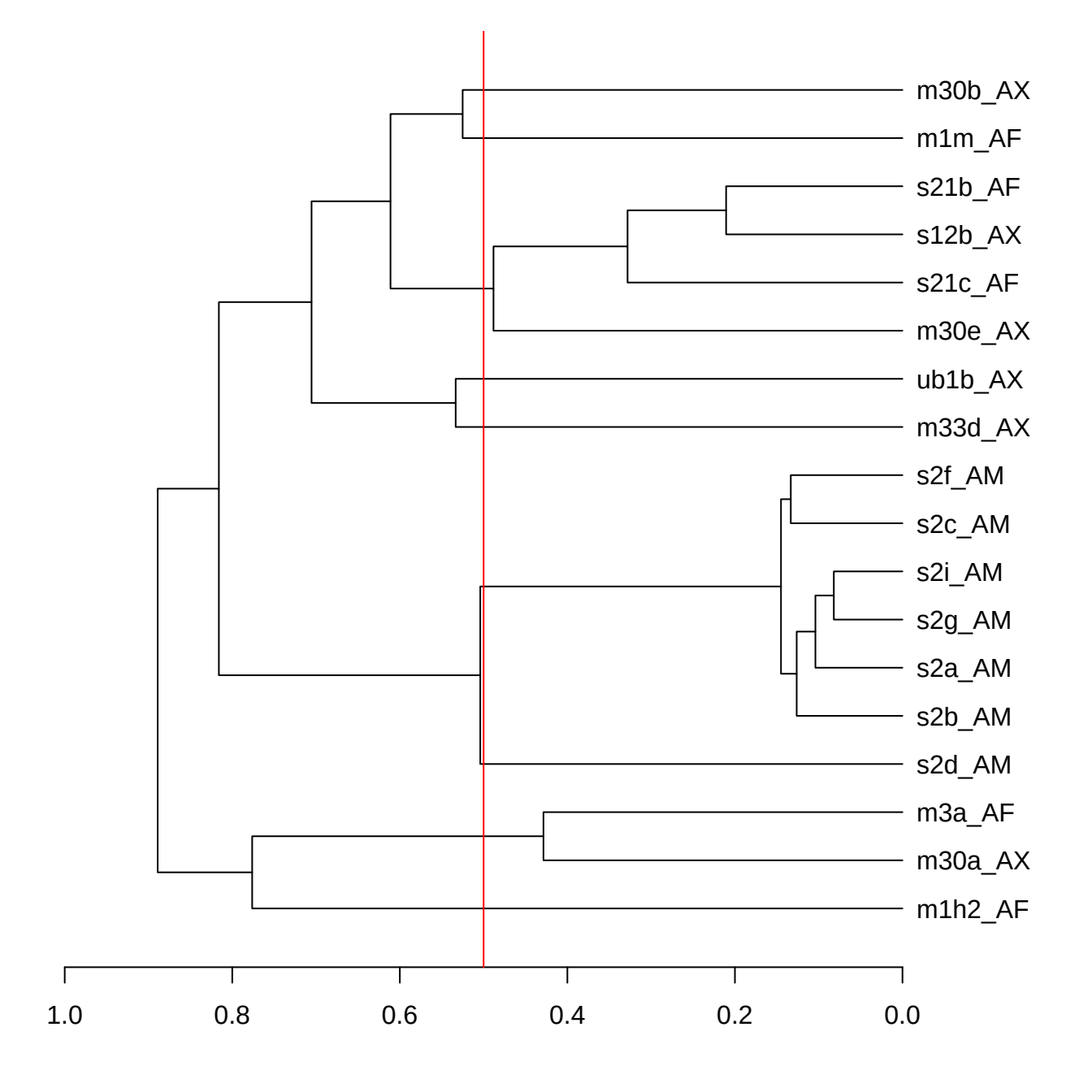
Appendix II

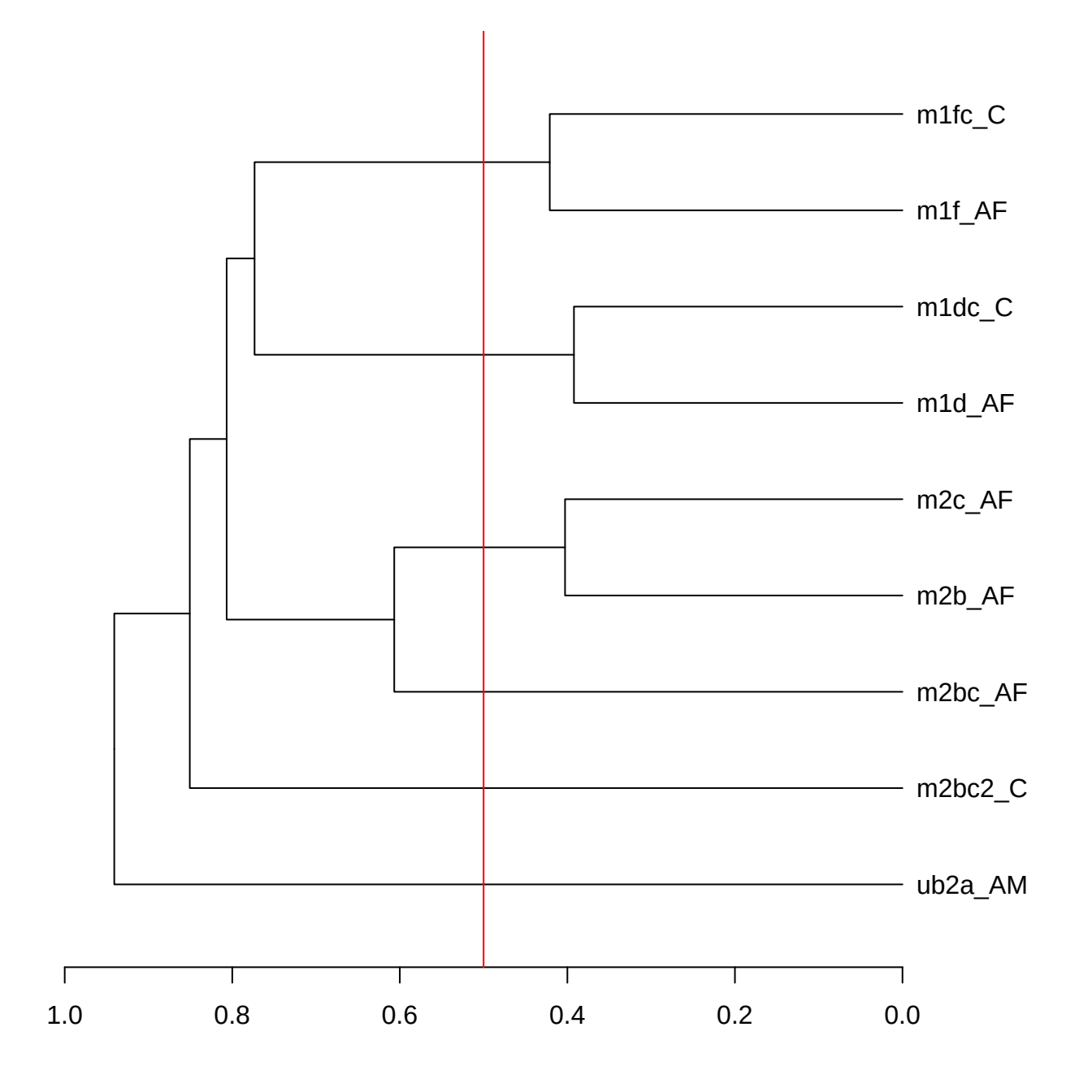
Dendrogram for all individuals sighted ≥ 10 times

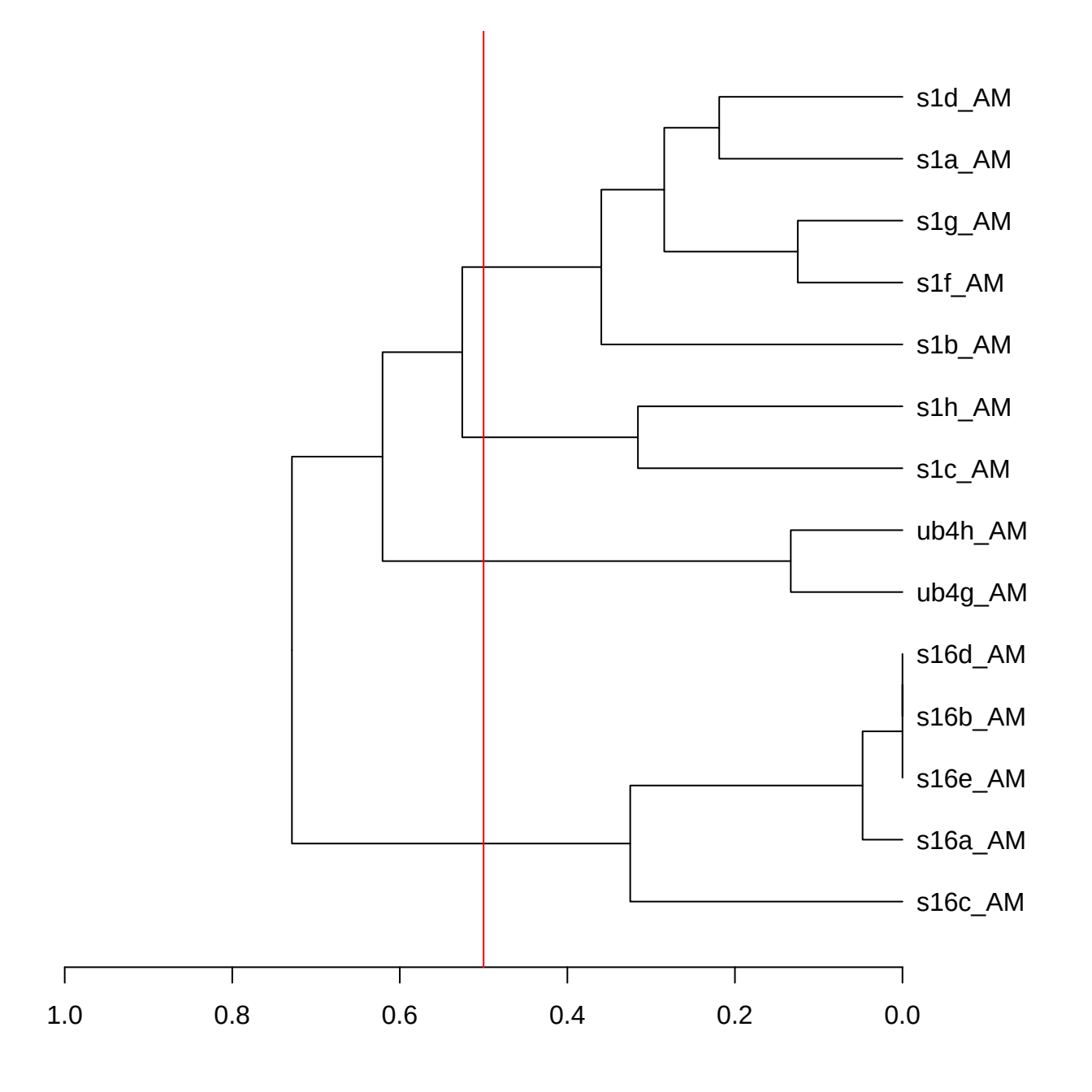
Average Linkage Method

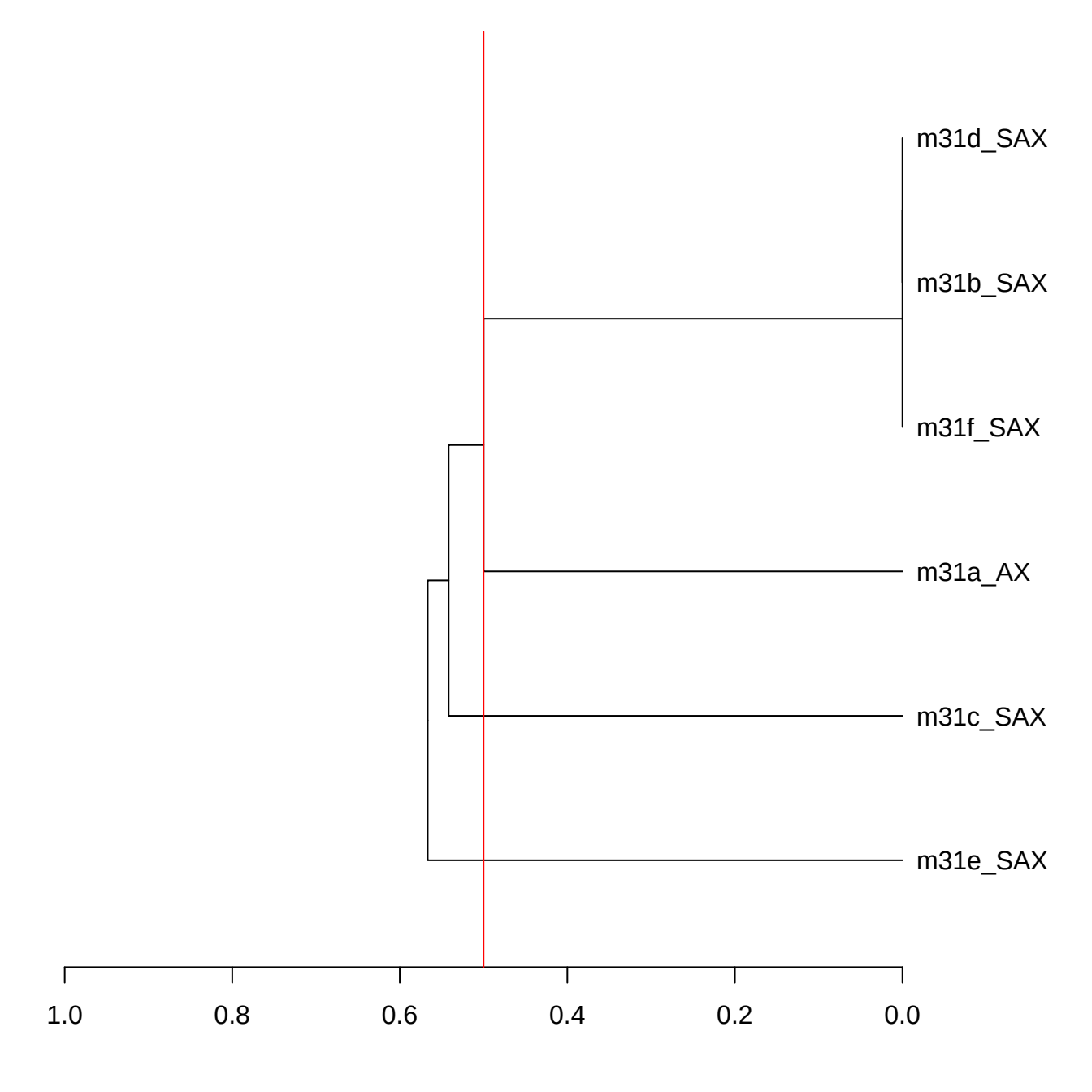

s1f _AM
m1xc _C
m1r_AF
1.0
0.8
0.6
0.4
0.2
0.0

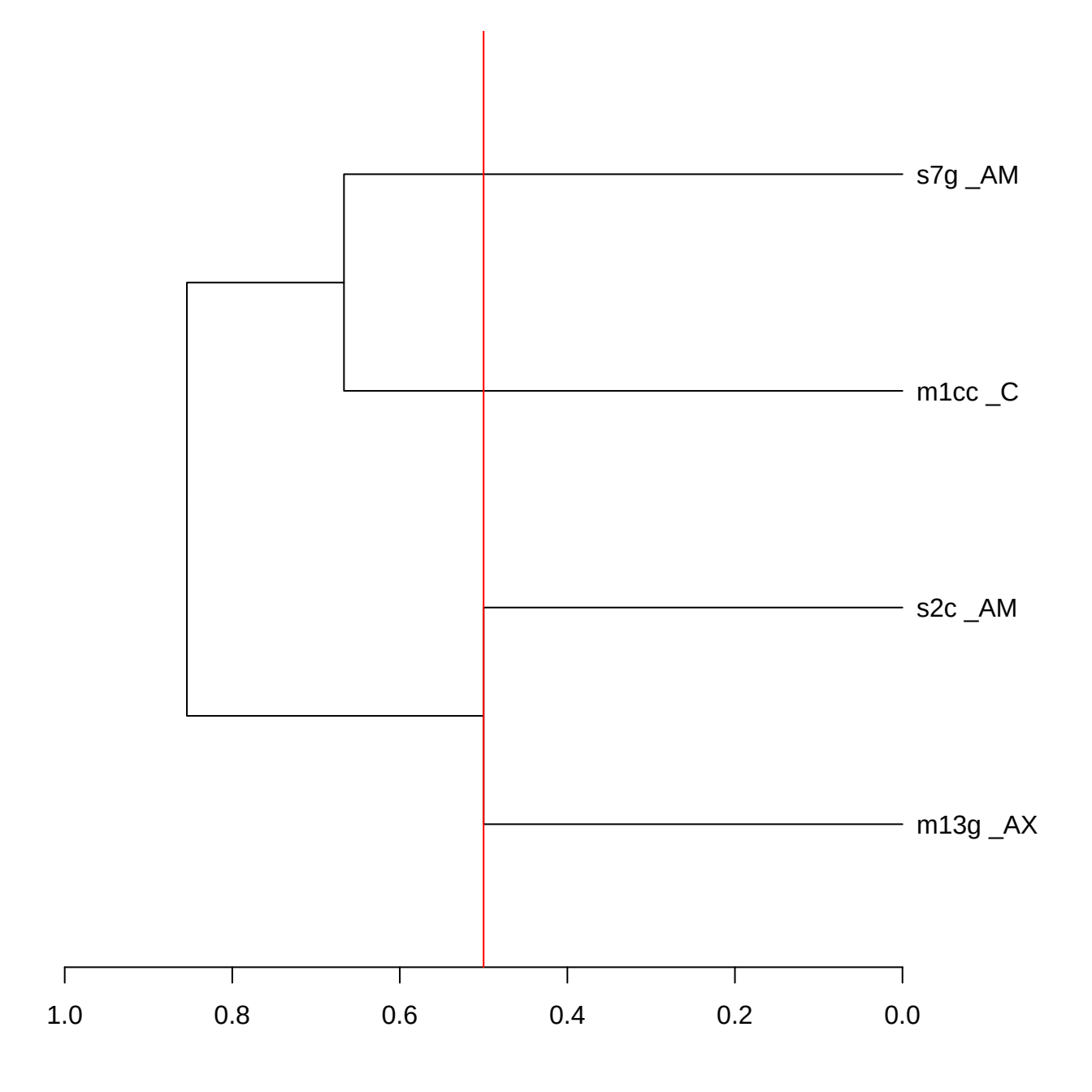

m31hc_C
m31h_AF
m1m3c_C
m1m3_AF
m1i4c_C
m29c_AF
m29c1_C
m1l4c_C
m1l4_AF
m1n3c_C
m1n3_AF
m1t4c_C
m1t4_AF
m1o3c_C
m1o3_AF
m1s4_AF
m1yc_C
m1y_AF
m1xc_C
m1x_AF
1.0
0.8
0.6
0.4
0.2
0.0

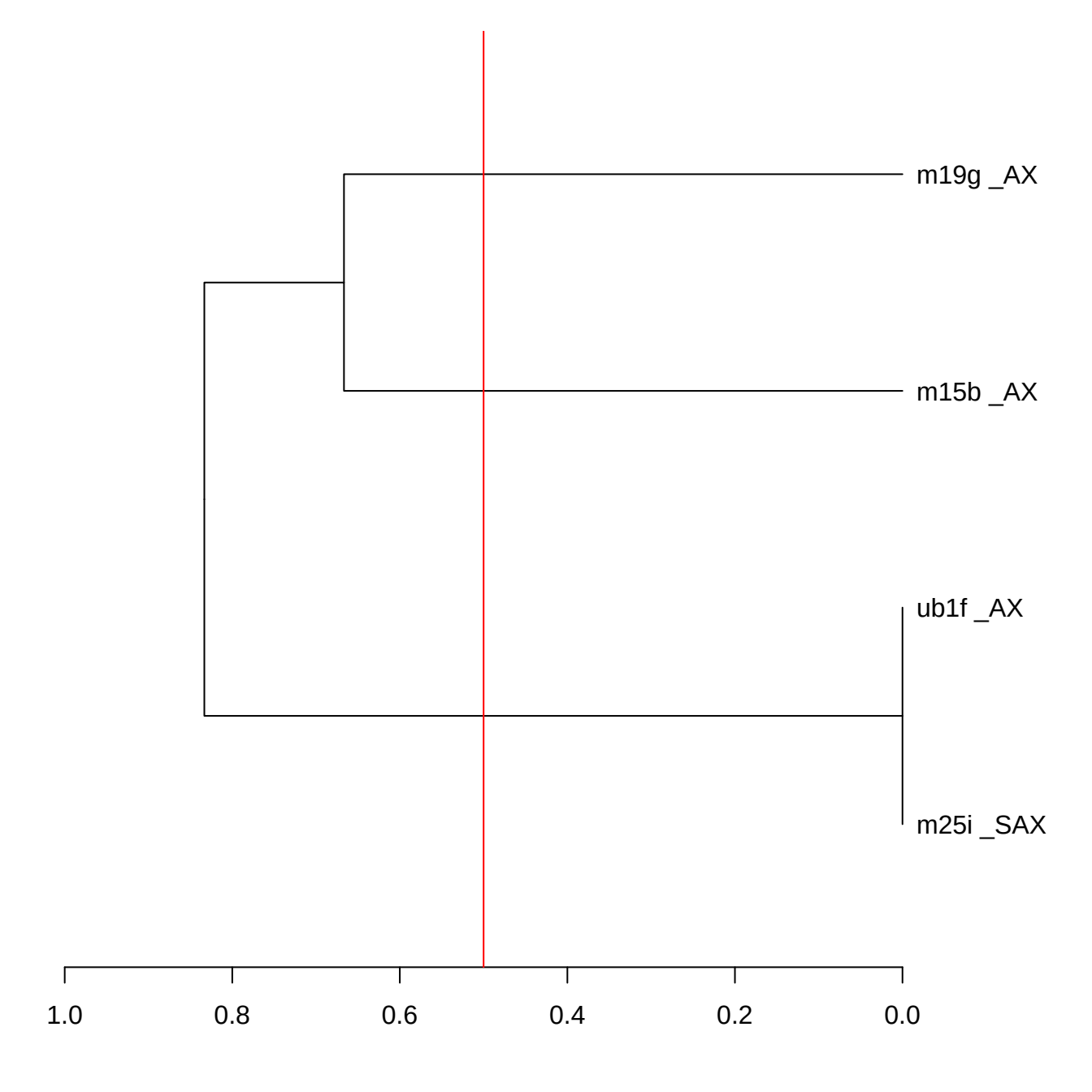

m30b_AX
m1m_AF
s21b_AF
s12b_AX
s21c_AF
m30e_AX
ub1b_AX
m33d_AX
s2f_AM
s2c_AM
s2i_AM
s2g_AM
s2a_AM
s2b_AM
s2d_AM
m3a_AF
m30a_AX
m1h2_AF
1.0
0.8
0.6
0.4
0.2
0.0

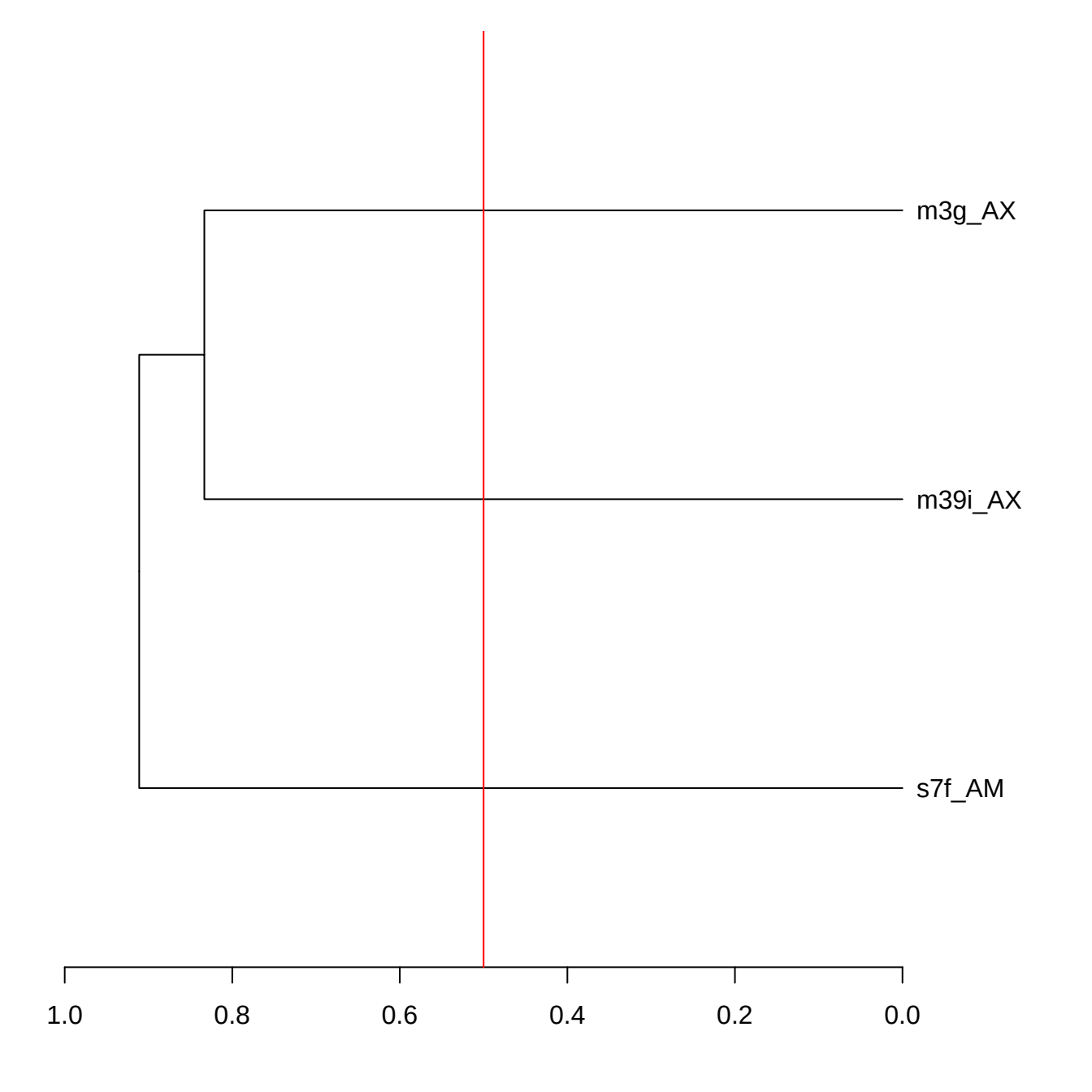

m1fc_C
m1f_AF
m1dc_C
m1d_AF
m2c_AF
m2b_AF
m2bc_AF
m2bc2_C
ub2a_AM
1.0
0.8
0.6
0.4
0.2
0.0

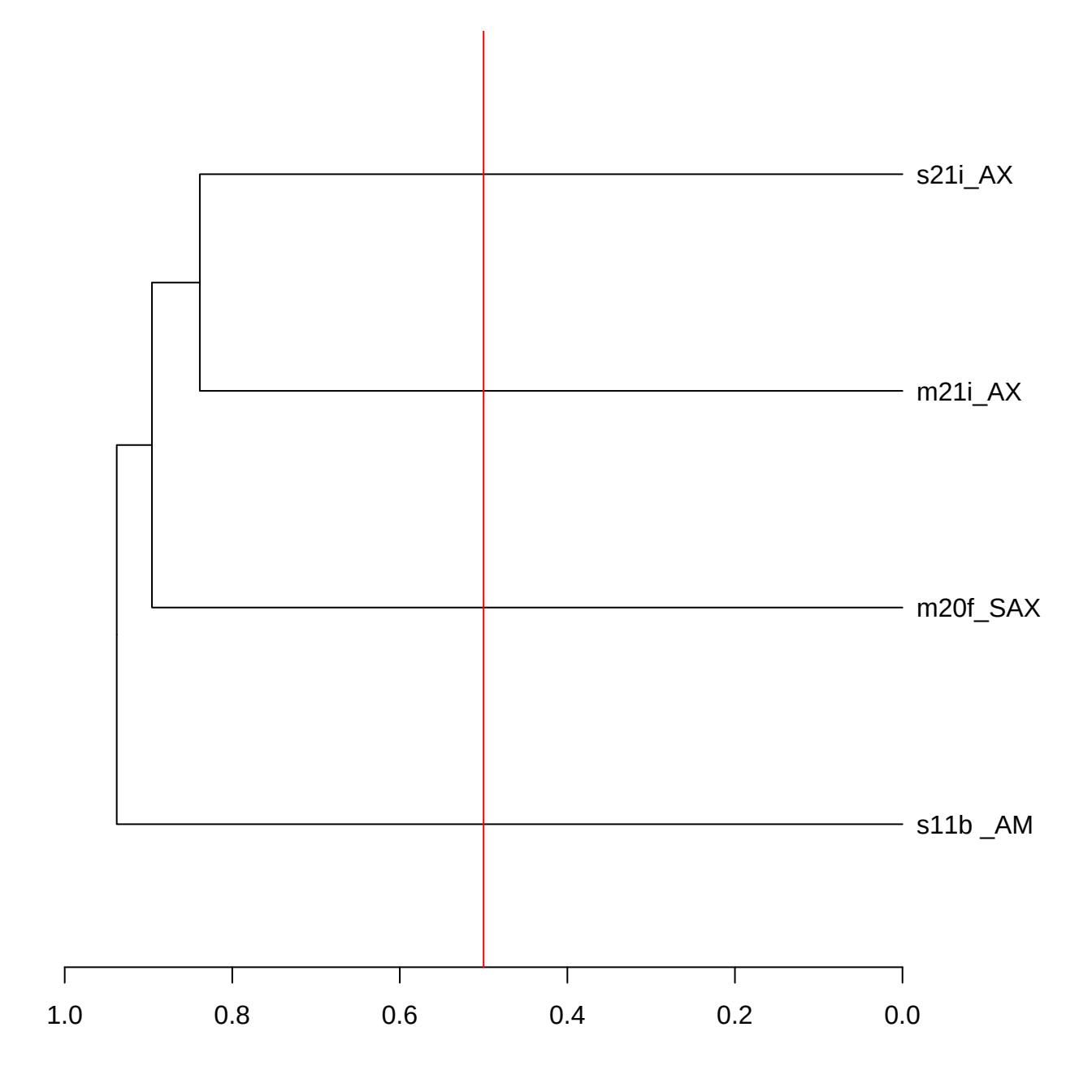

s1d_AM
s1a_AM
s1g_AM
s1f_AM
s1b_AM
s1h_AM
s1c_AM
ub4h_AM
ub4g_AM
s16d_AM
s16b_AM
s16e_AM
s16a_AM
s16c_AM
1.0
0.8
0.6
0.4
0.2
0.0

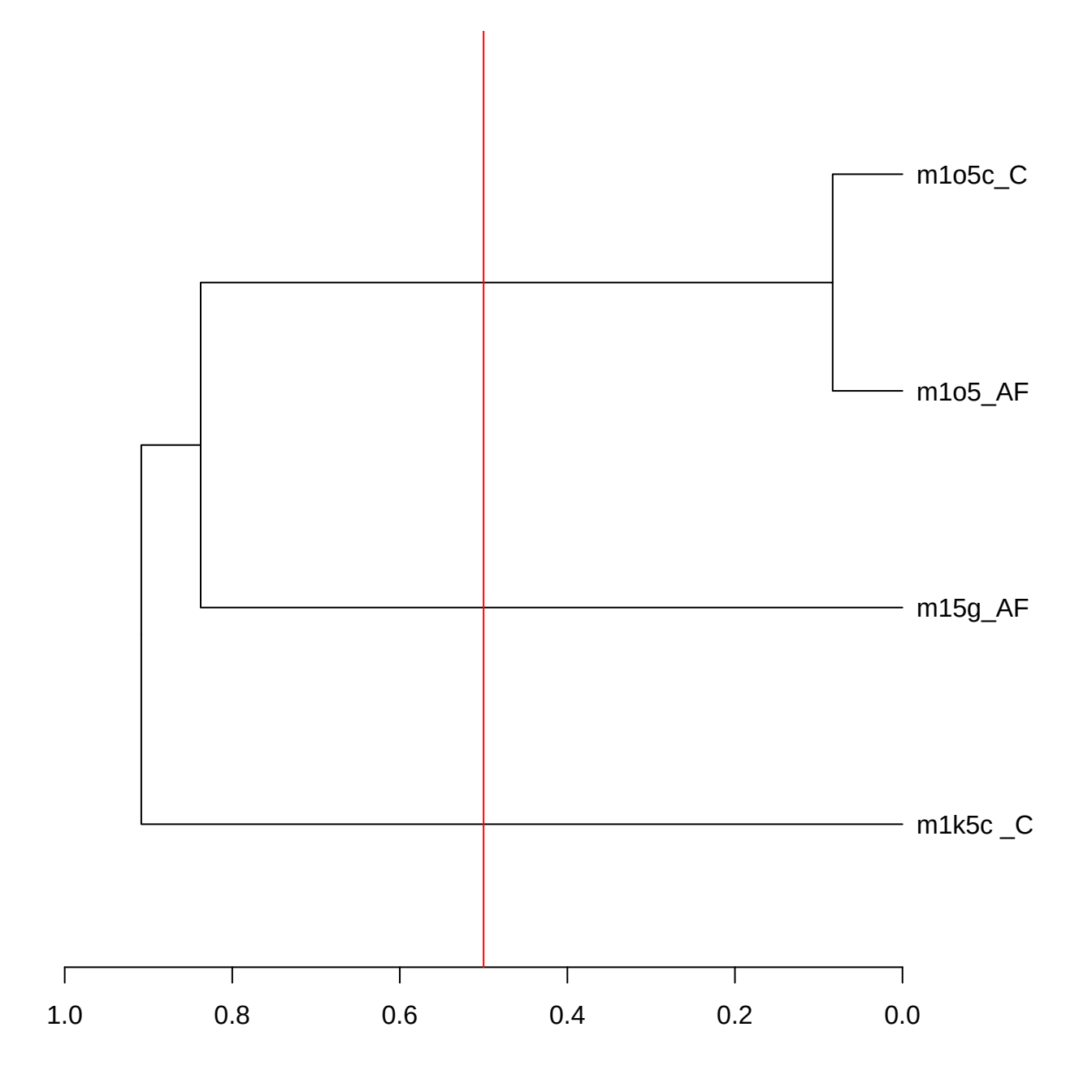

m31d_SAX
m31b_SAX
m31f_SAX
m31a_AX
m31c_SAX
m31e_SAX
1.0
0.8
0.6
0.4
0.2
0.0


s7g _AM
m1cc _C
s2c _AM
m13g _AX
1.0
0.8
0.6
0.4
0.2
0.0


m19g _AX
m15b _AX
ub1f _AX
m25i _SAX
1.0
0.8
0.6
0.4
0.2
0.0


m3g_AX
m39i_AX
s7f_AM
1.0
0.8
0.6
0.4
0.2
0.0


s21i_AX
m21i_AX
m20f_SAX
s11b _AM
1.0
0.8
0.6
0.4
0.2
0.0


m1o5c_C
m1o5_AF
m15g_AF
m1k5c _C
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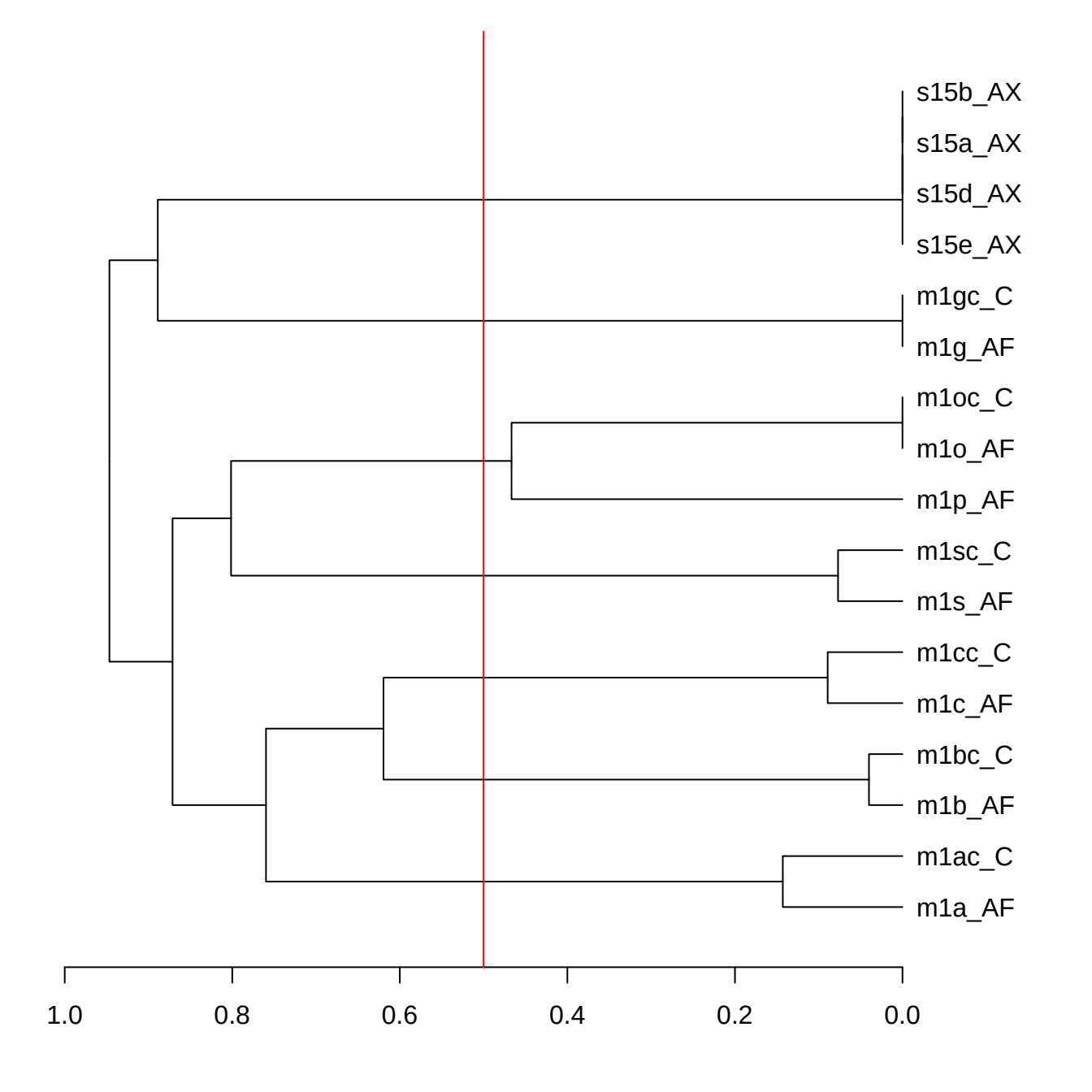
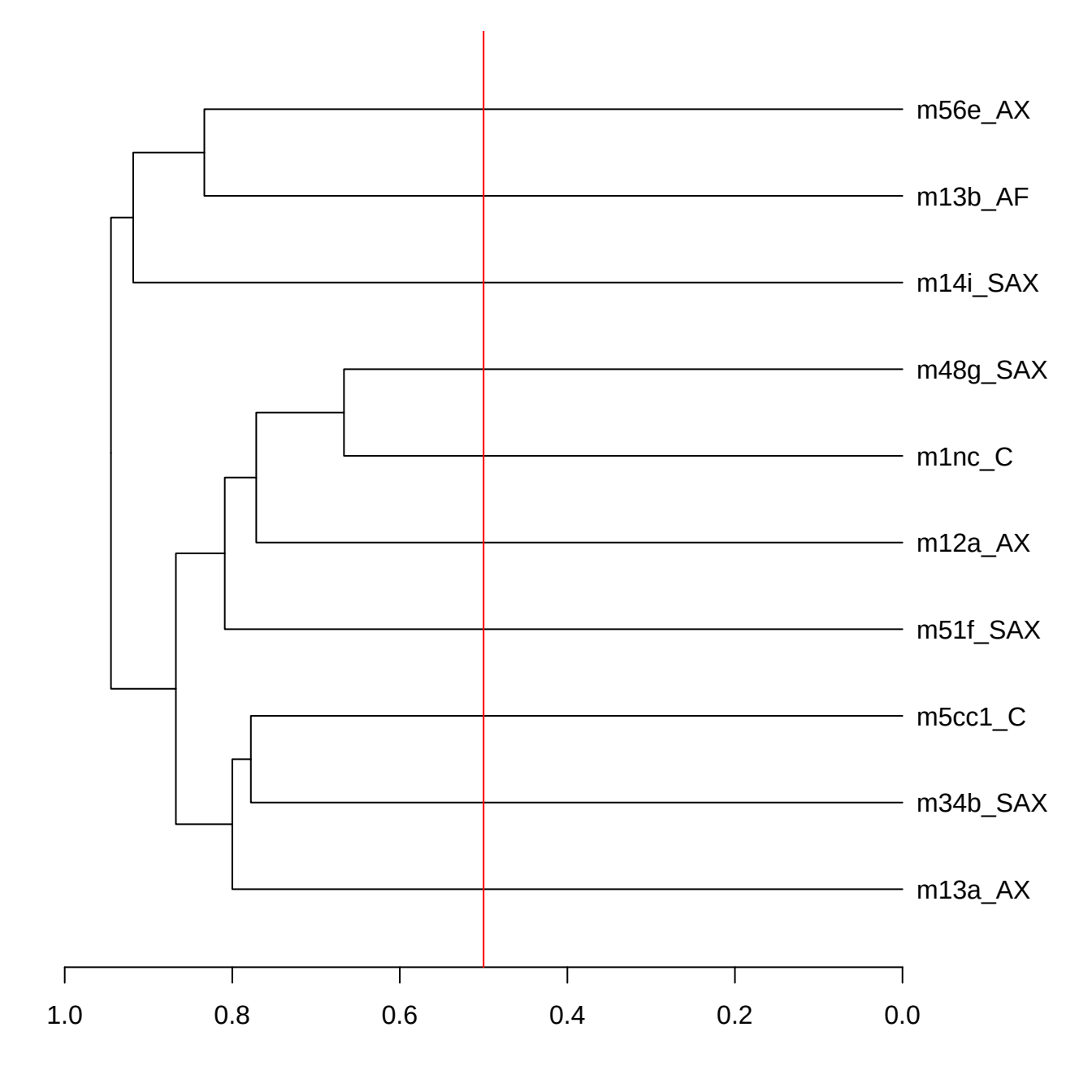
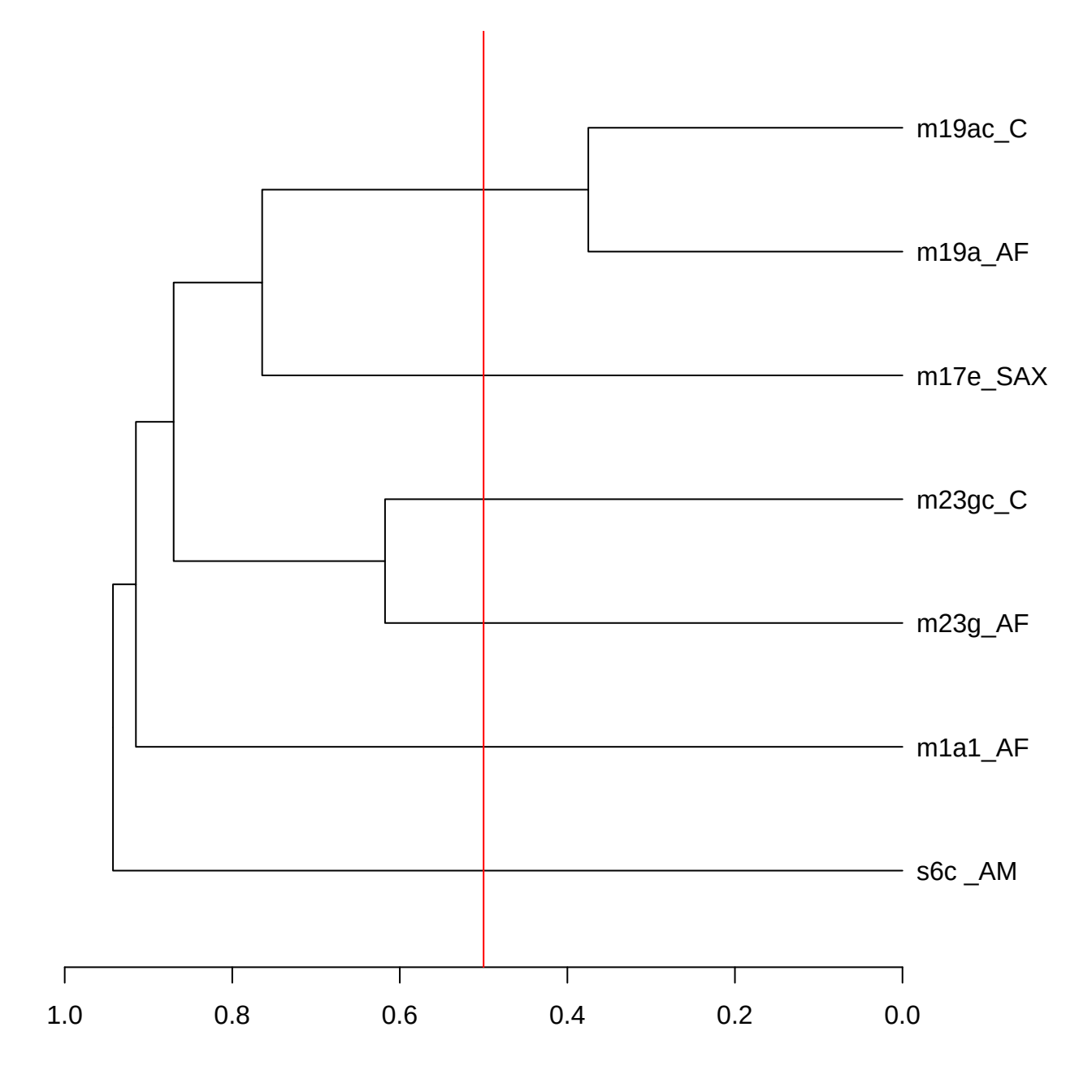
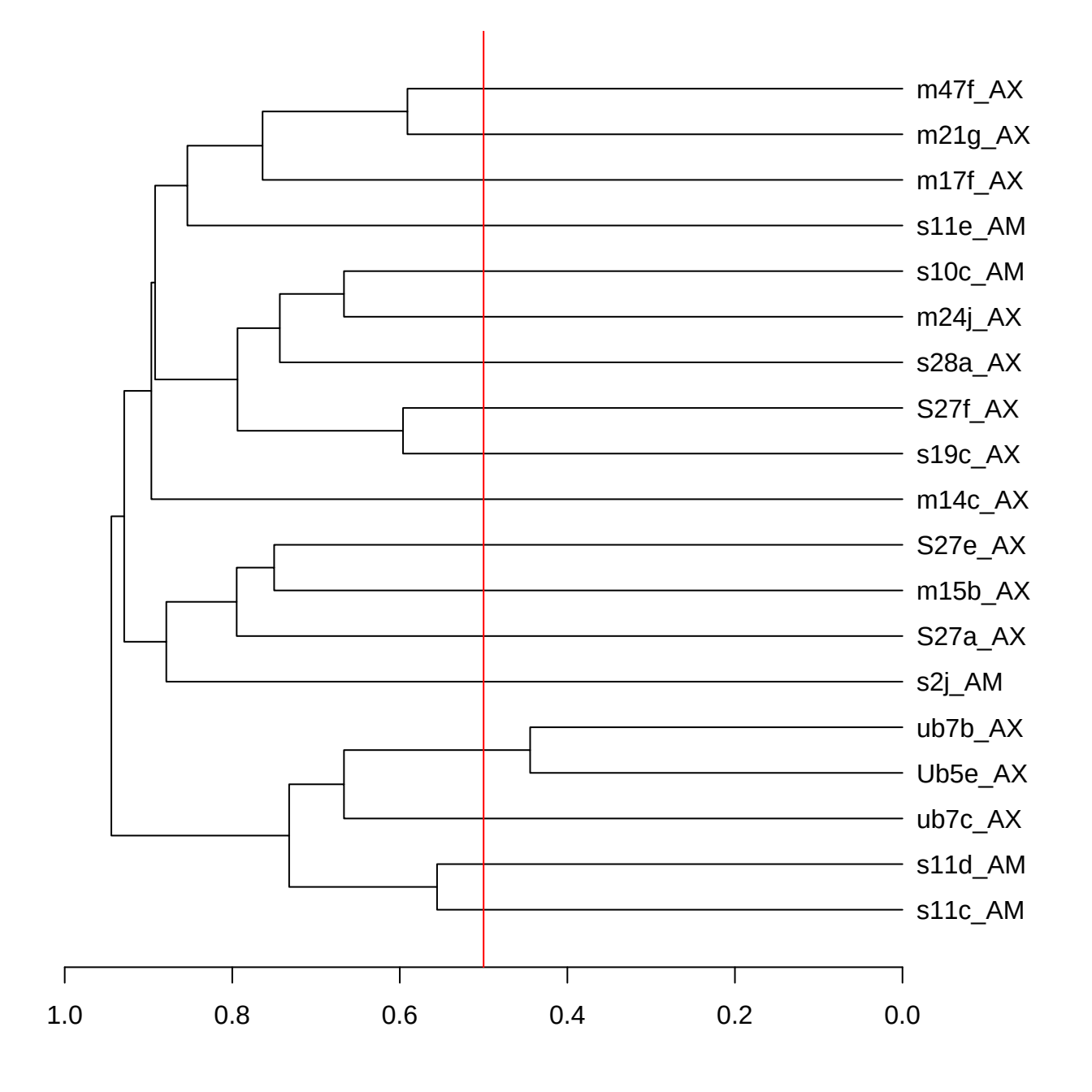
0.8
0.6
0.4
0.2
0.0


s15b_AX
s15a_AX
s15d_AX
s15e_AX
m1gc_C
m1g_AF
m1oc_C
m1o_AF
m1p_AF
m1sc_C
m1s_AF
m1cc_C
m1c_AF
m1bc_C
m1b_AF
m1ac_C
m1a_AF
1.0
0.8
0.6
0.4
0.2
0.0


m56e_AX
m13b_AF
m14i_SAX
m48g_SAX
m1nc_C
m12a_AX
m51f_SAX
m5cc1_C
m34b_SAX
m13a_AX
1.0
0.8
0.6
0.4
0.2
0.0


m19ac_C
m19a_AF
m17e_SAX
m23gc_C
m23g_AF
m1a1_AF
s6c _AM
1.0
0.8
0.6
0.4
0.2
0.0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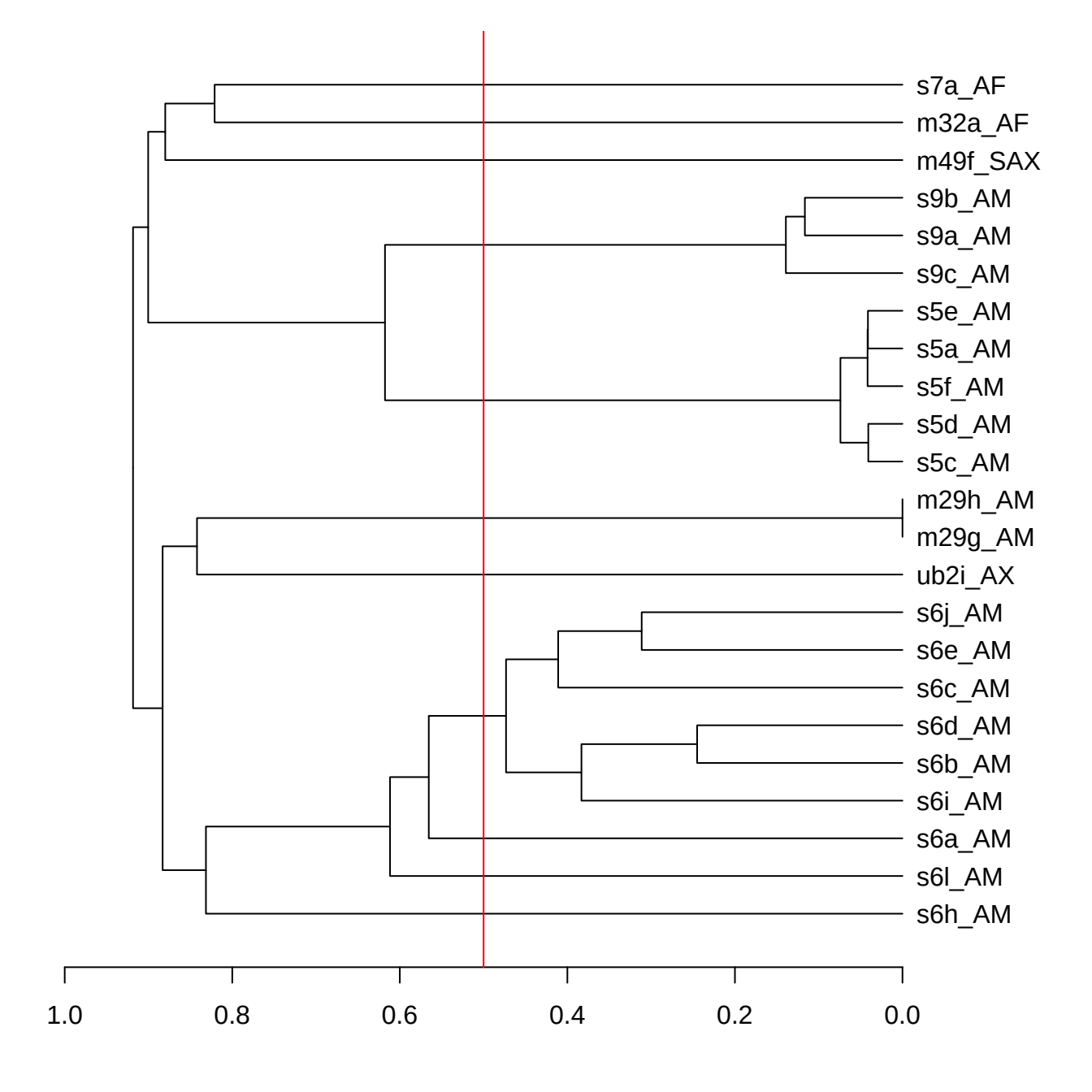
m21g_AX
m17f_AX
s11e_AM
s10c_AM
m24j_AX
s28a_AX
S27f_AX
s19c_AX
m14c_AX
S27e_AX
m15b_AX
S27a_AX
s2j_AM
ub7b_AX
Ub5e_AX
ub7c_AX
s11d_AM
s11c_AM
1.0
0.8
0.6
0.4
0.2
0.0


s7a_AF
m32a_AF
m49f_SAX
s9b_AM
s9a_AM
s9c_AM
s5e_AM
s5a_AM
s5f_AM
s5d_AM
s5c_AM
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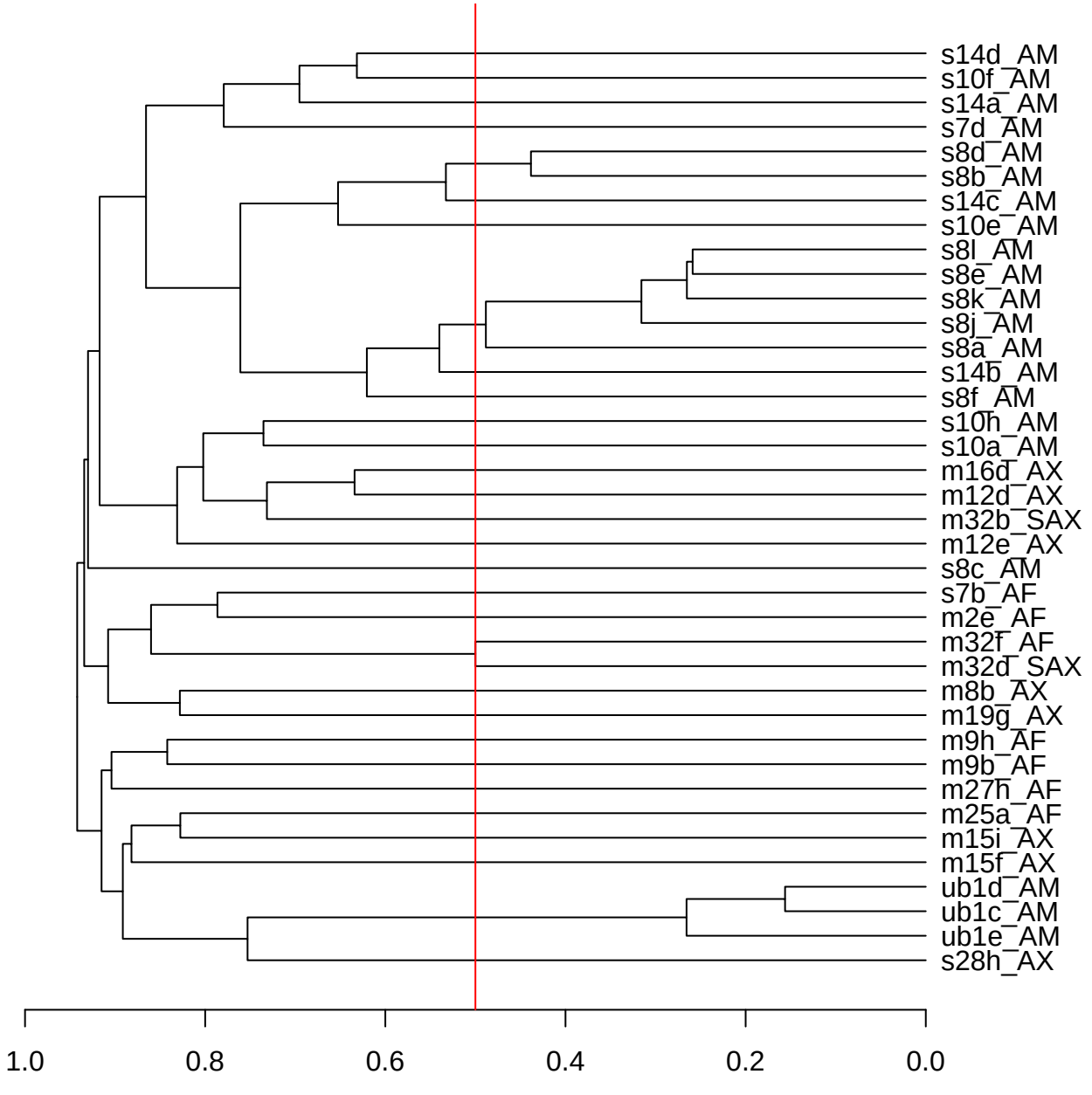
s6e_AM
s6c_AM
s6d_AM
s6b_AM
s6i_AM
s6a_AM
s6l_AM
s6h_AM
1.0
0.8
0.6
0.4
0.2
0.0


s14d_AM
s10f_AM
s14a_AM
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s8d_AM
s8b_AM
s14c_AM
s10e_AM
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s8e_AM
s8k_AM
s8j_AM
s8a_AM
s14b_AM
s8f_AM
s10h_AM
s10a_AM
m16d_AX
m12d_AX
m32b_SAX
m12e_AX
s8c_AM
s7b_AF
m2e_AF
m32f_AF
m32d_SAX
m8b_AX
m19g_AX
m9h_AF
m9b_AF
m27h_AF
m25a_AF
m15i_AX
m15f_AX
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ub1e_AM
s28h_AX
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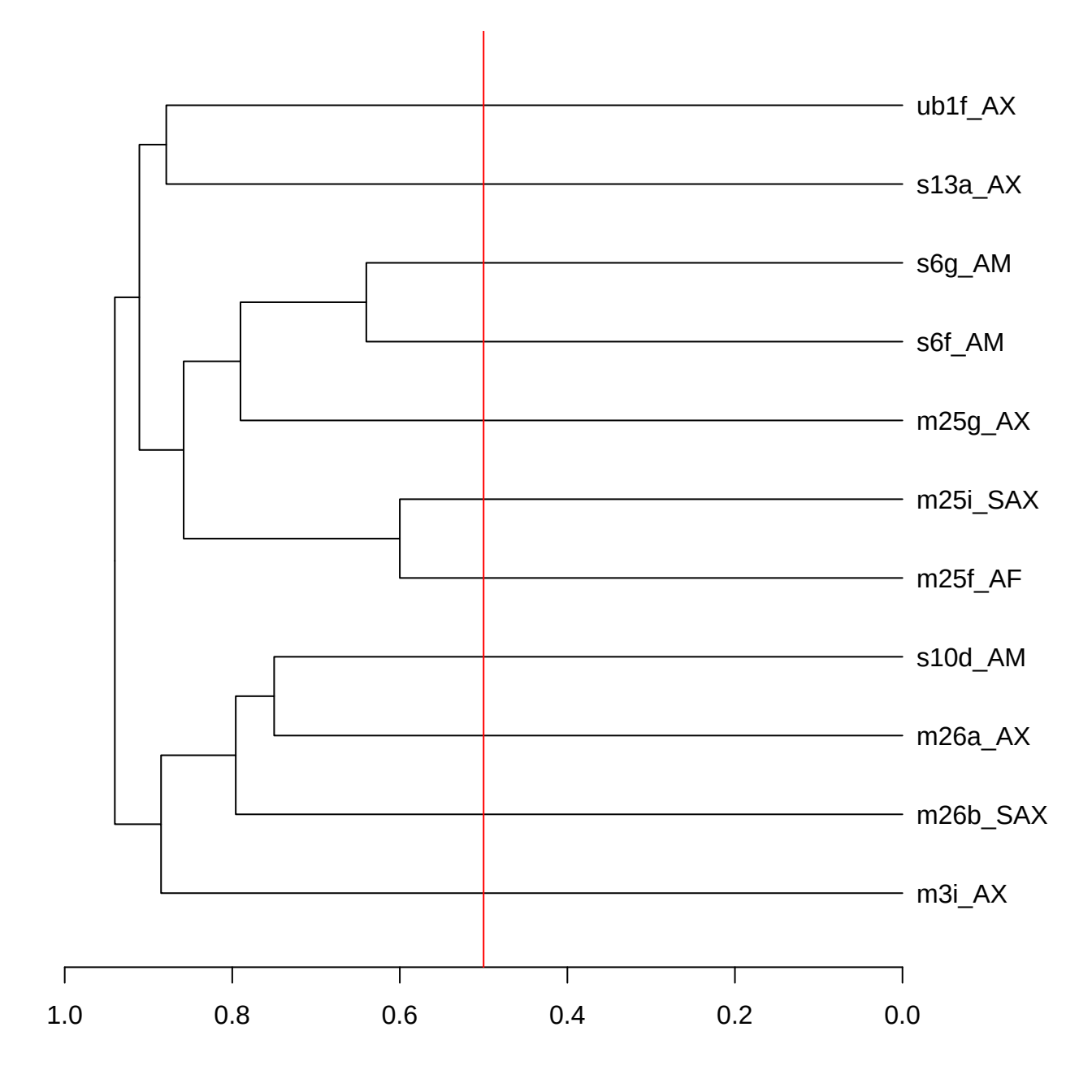
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m25f_AF
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m3i_AX
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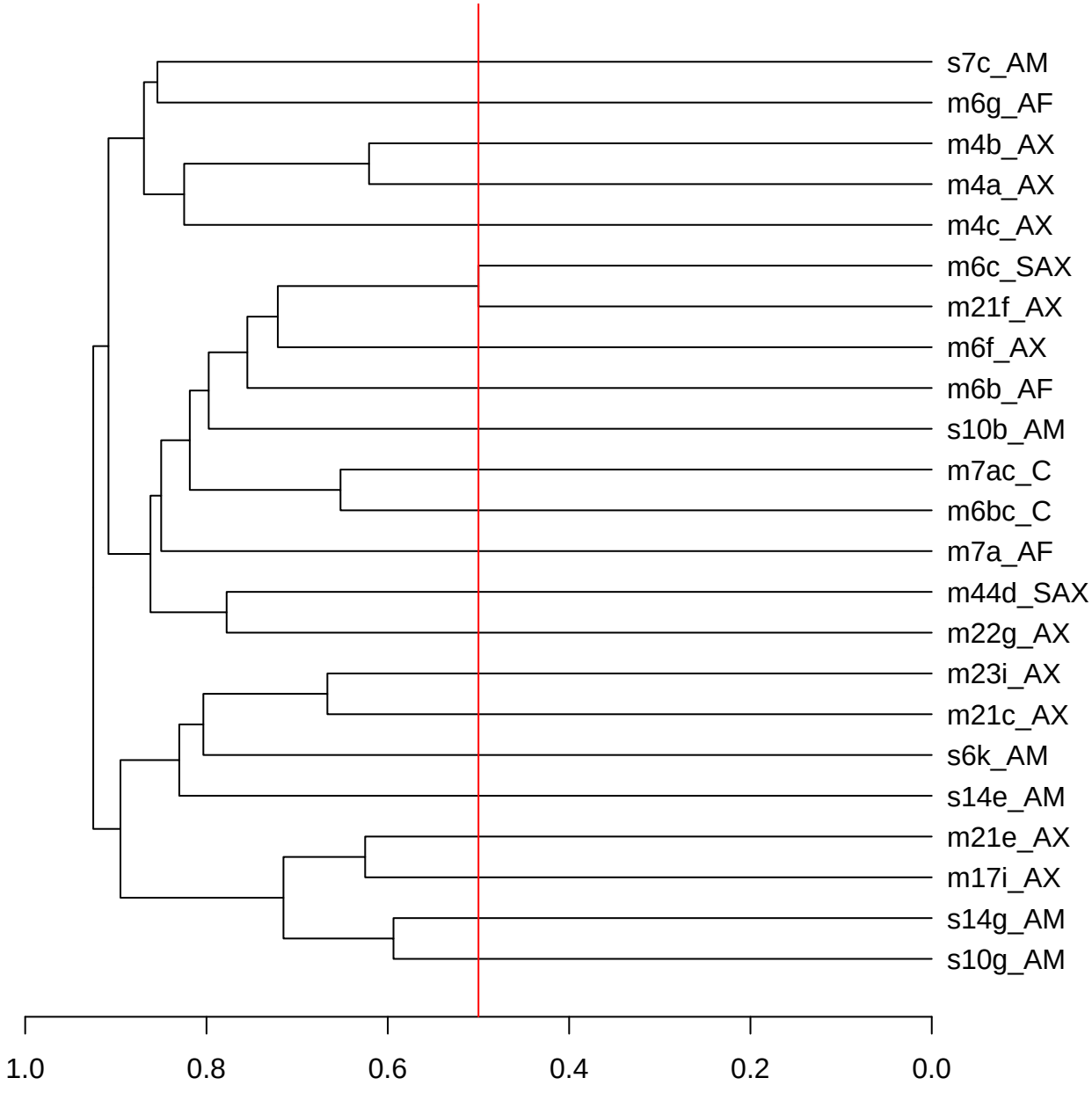
0.2
0.0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m4a_AX
m4c_AX
m6c_SAX
m21f_AX
m6f_AX
m6b_AF
s10b_AM
m7ac_C
m6bc_C
m7a_AF
m44d_SAX
m22g_AX
m23i_AX
m21c_AX
s6k_AM
s14e_AM
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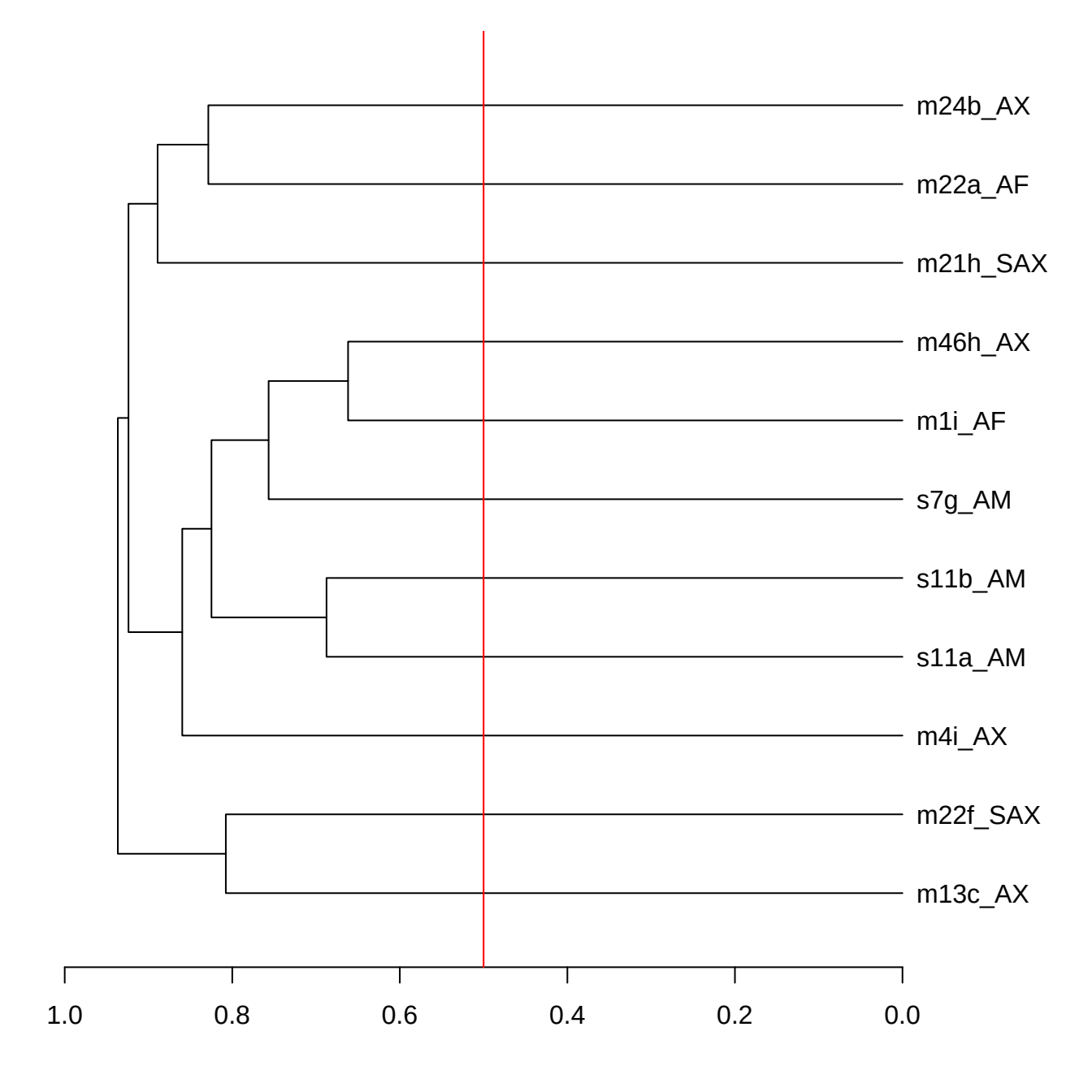
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s11b_AM
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m13c_AX
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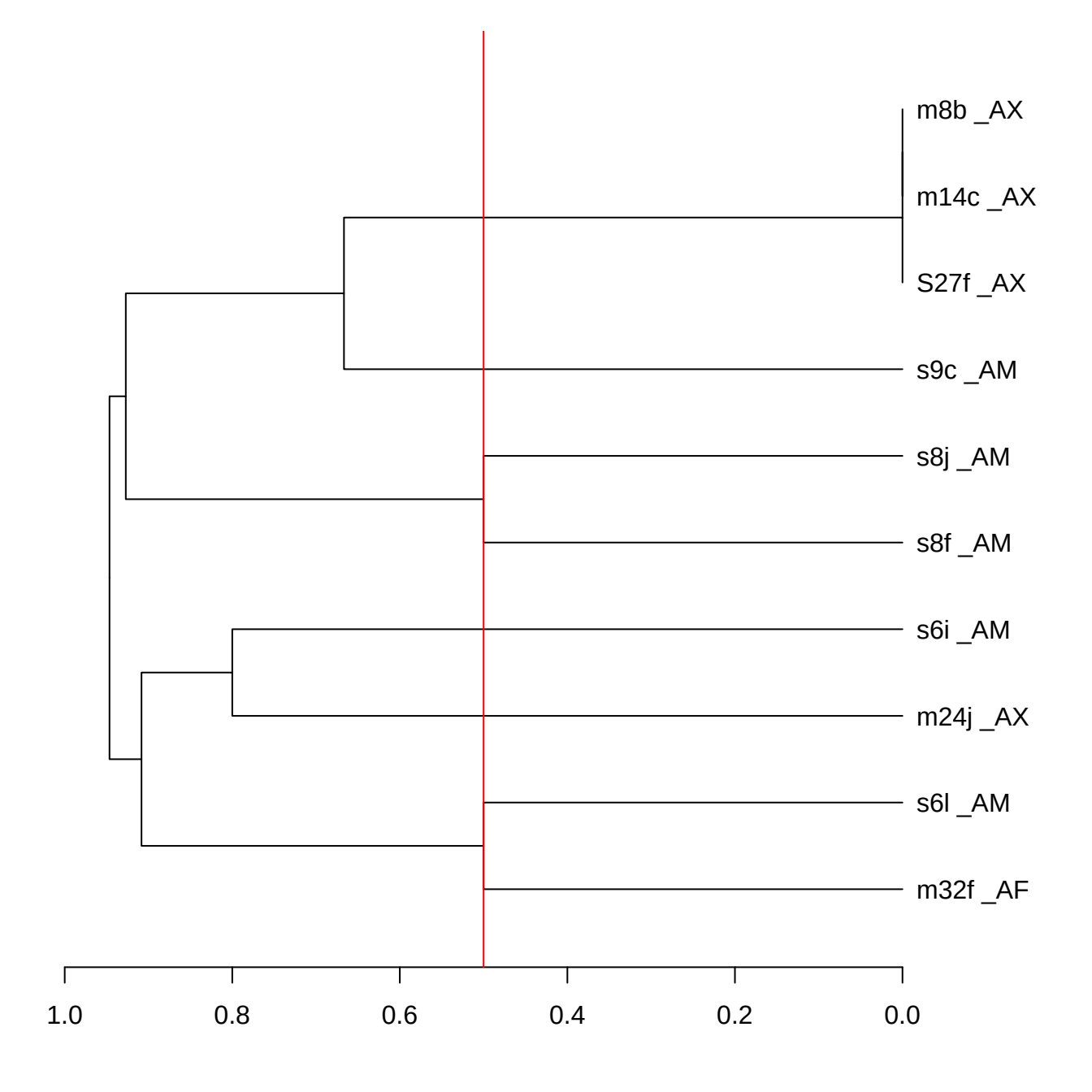
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S27f _AX
s9c _AM
s8j _AM
s8f _AM
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s6l _AM
m32f _AF
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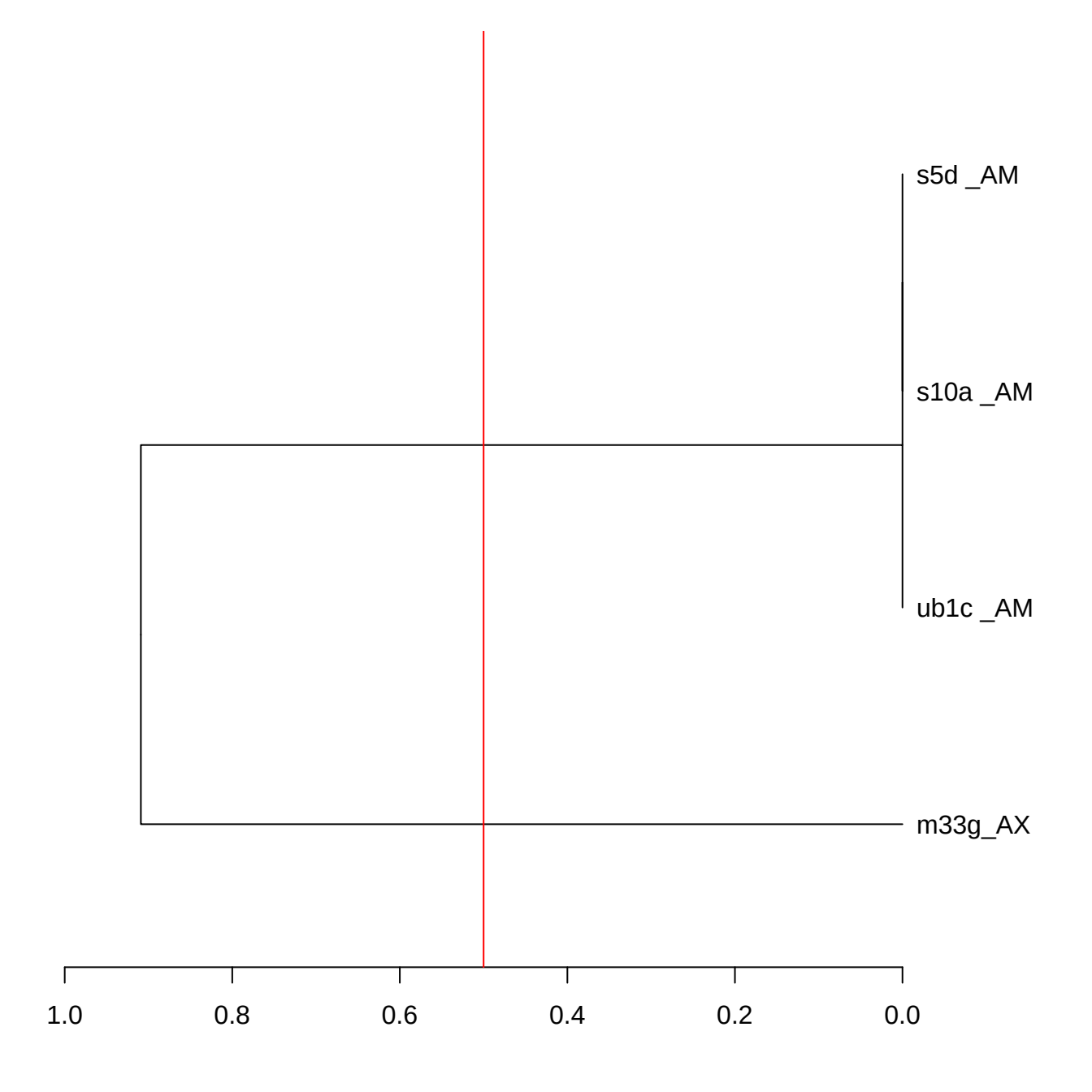
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s10a _AM
ub1c _AM
m33g_AX
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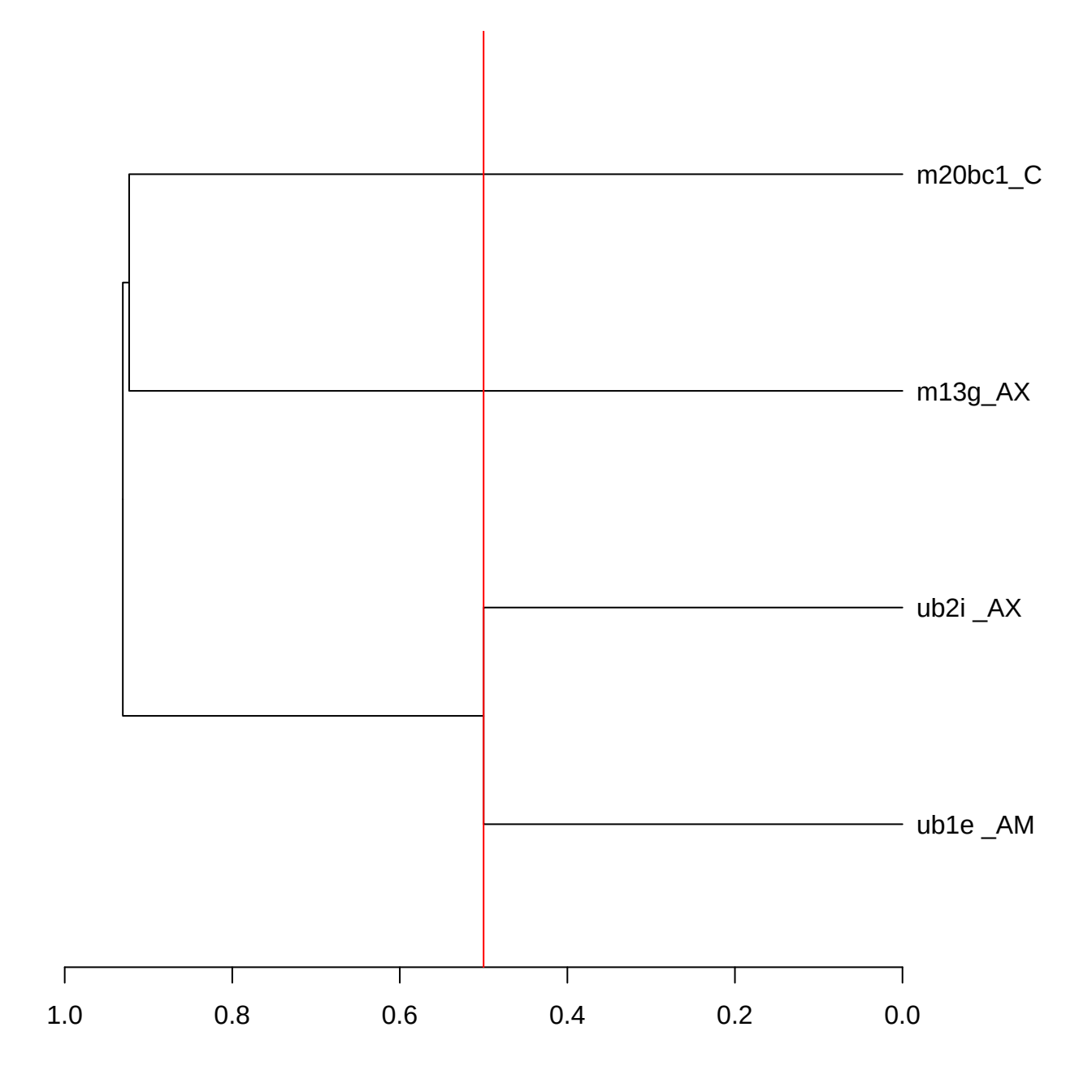
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m13g_AX
ub2i _AX
ub1e _AM
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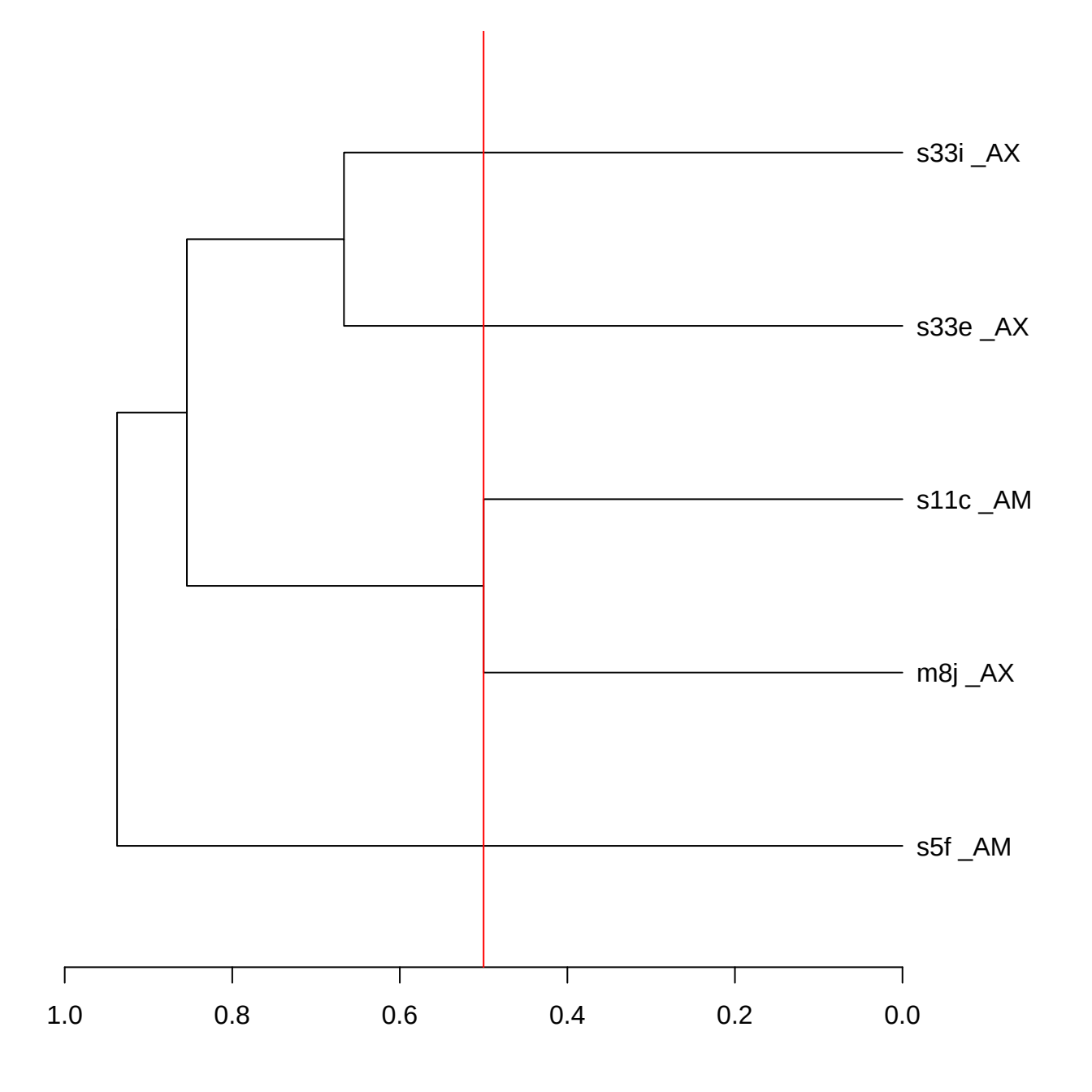
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s33e _AX
s11c _AM
m8j _AX
s5f _AM
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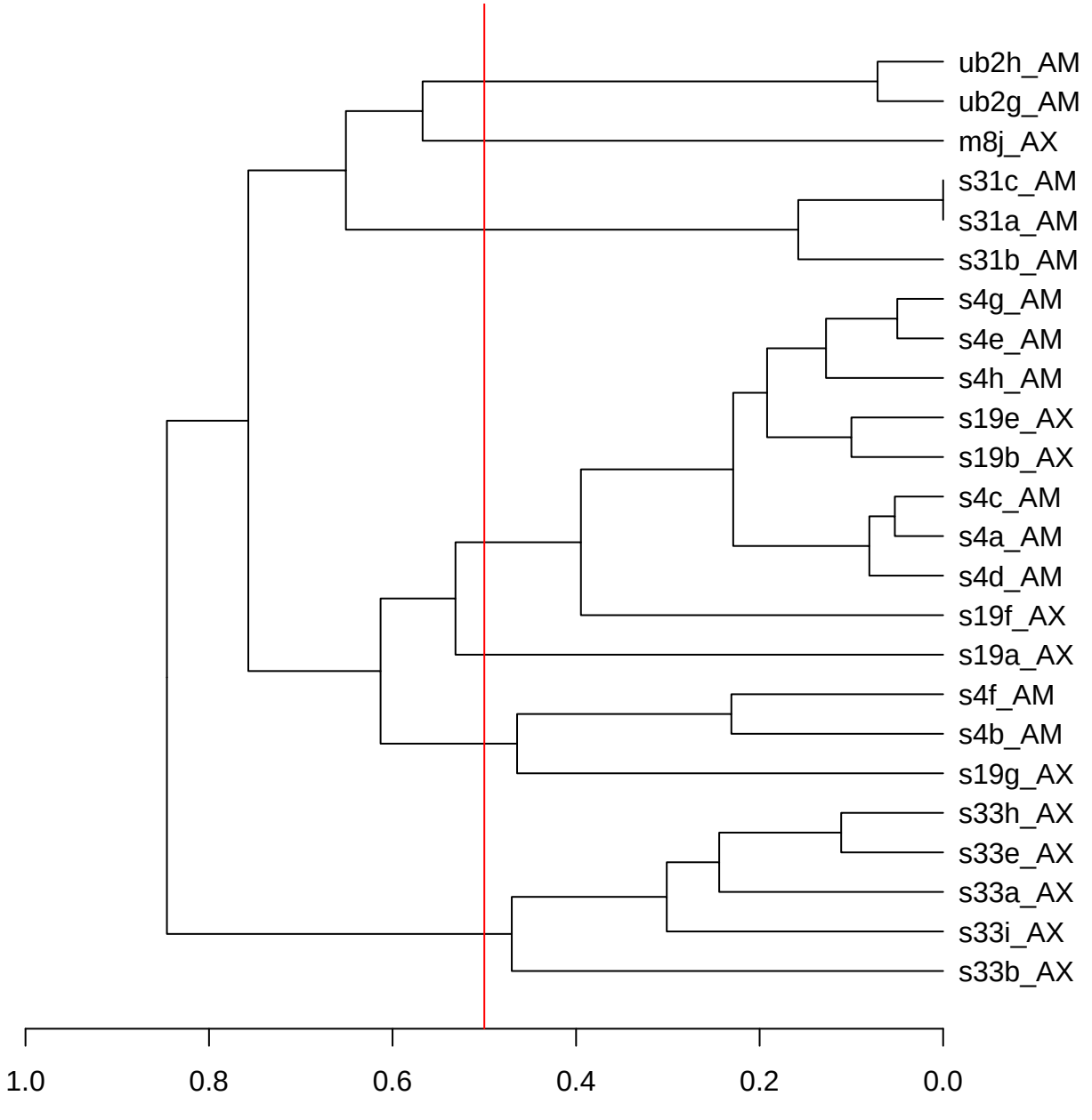
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ub2g_AM
m8j_AX
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s31a_AM
s31b_AM
s4g_AM
s4e_AM
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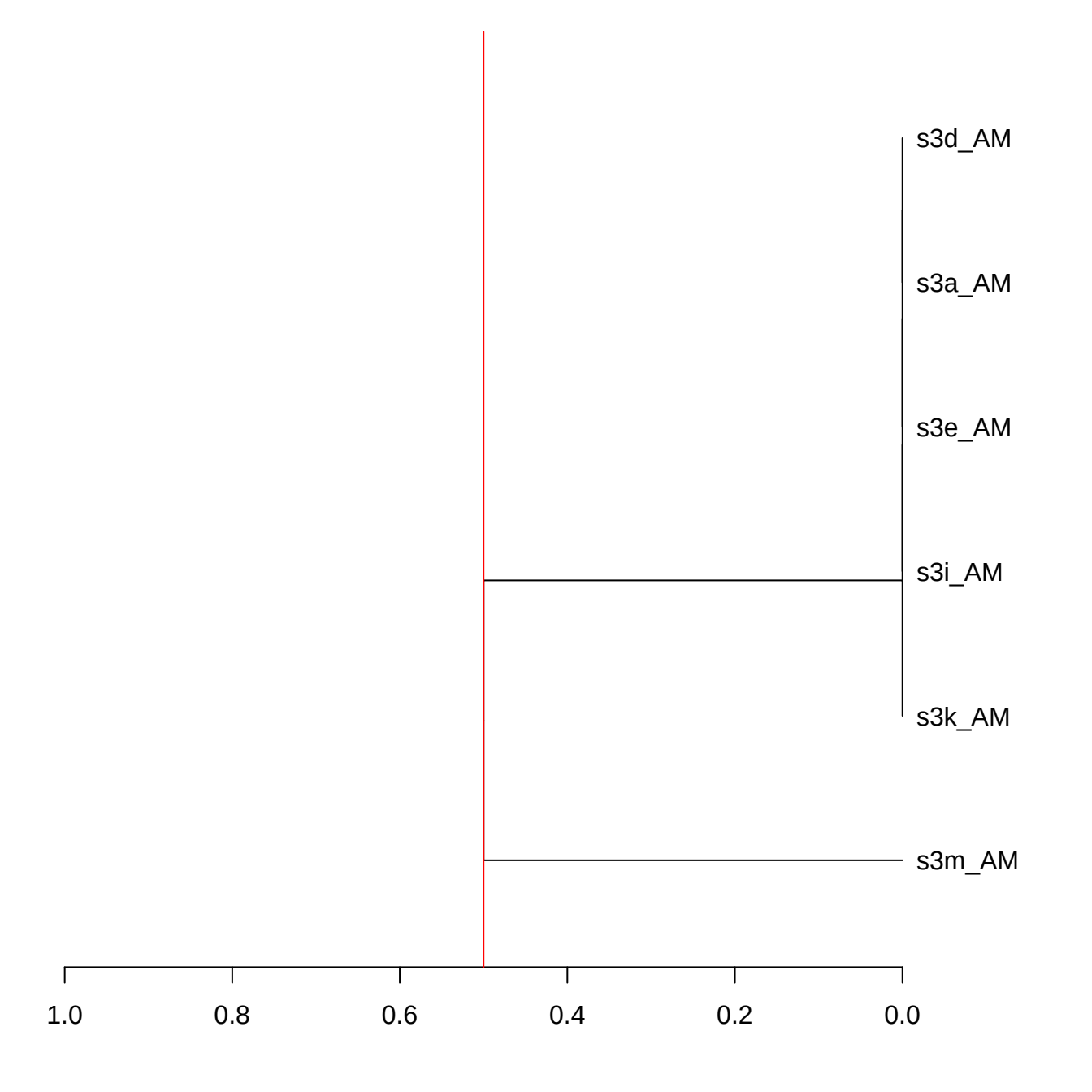
s4d_AM
s19f_AX
s19a_AX
s4f_AM
s4b_AM
s19g_AX
s33h_AX
s33e_AX
s33a_AX
s33i_AX
s33b_AX
1.0
0.8
0.6
0.4
0.2
0.0

Appendix III

Dendrogram for all individuals sighted ≥ 2 times

Complete Linkage Method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s3a_AM
s3e_AM
s3i_AM
s3k_AM
s3m_AM
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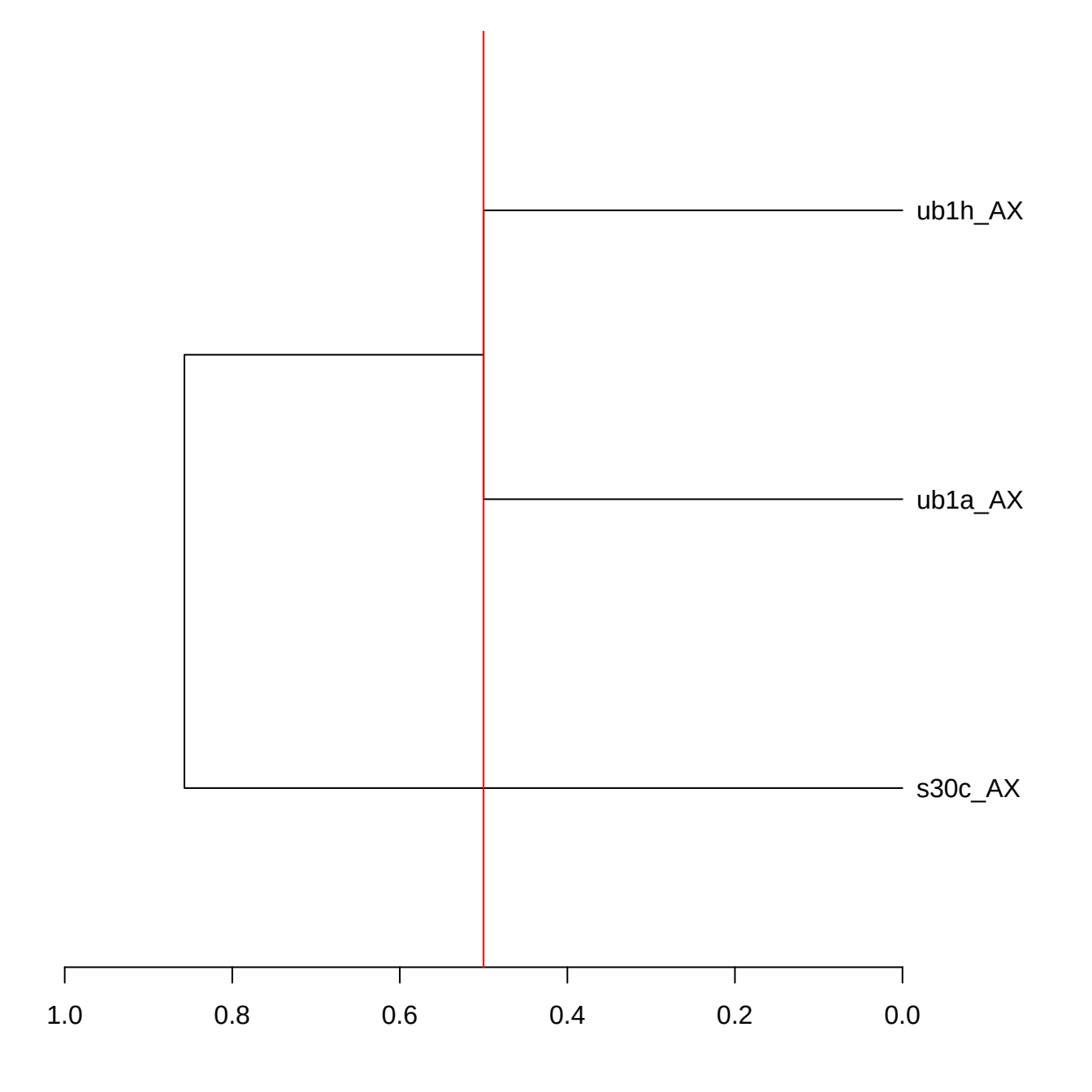
0.6
0.4
0.2
0.0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ub1a_AX
s30c_AX
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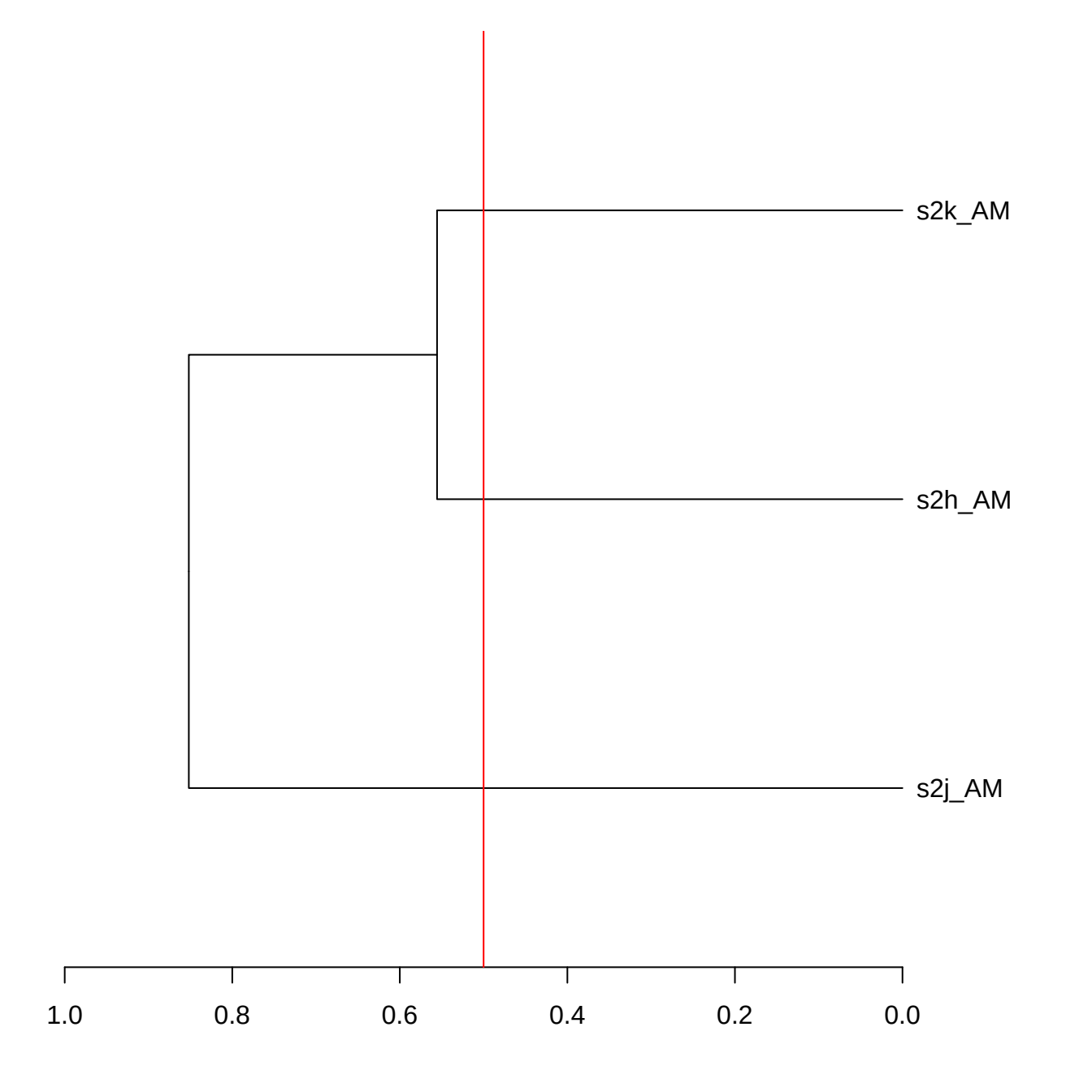
0.6
0.4
0.2
0.0


s2k_AM
s2h_AM
s2j_AM
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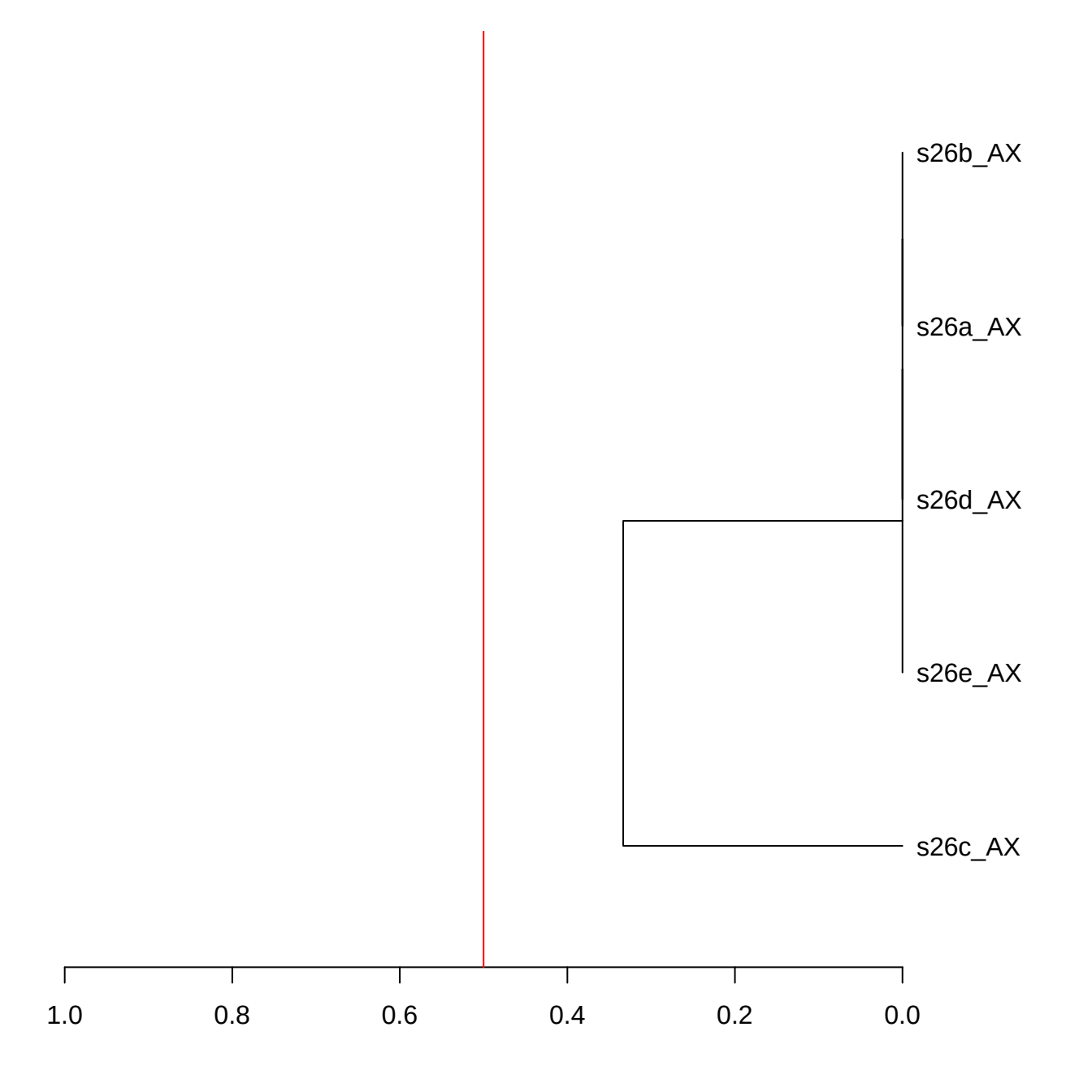
0.6
0.4
0.2
0.0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s26e_AX
s26c_AX
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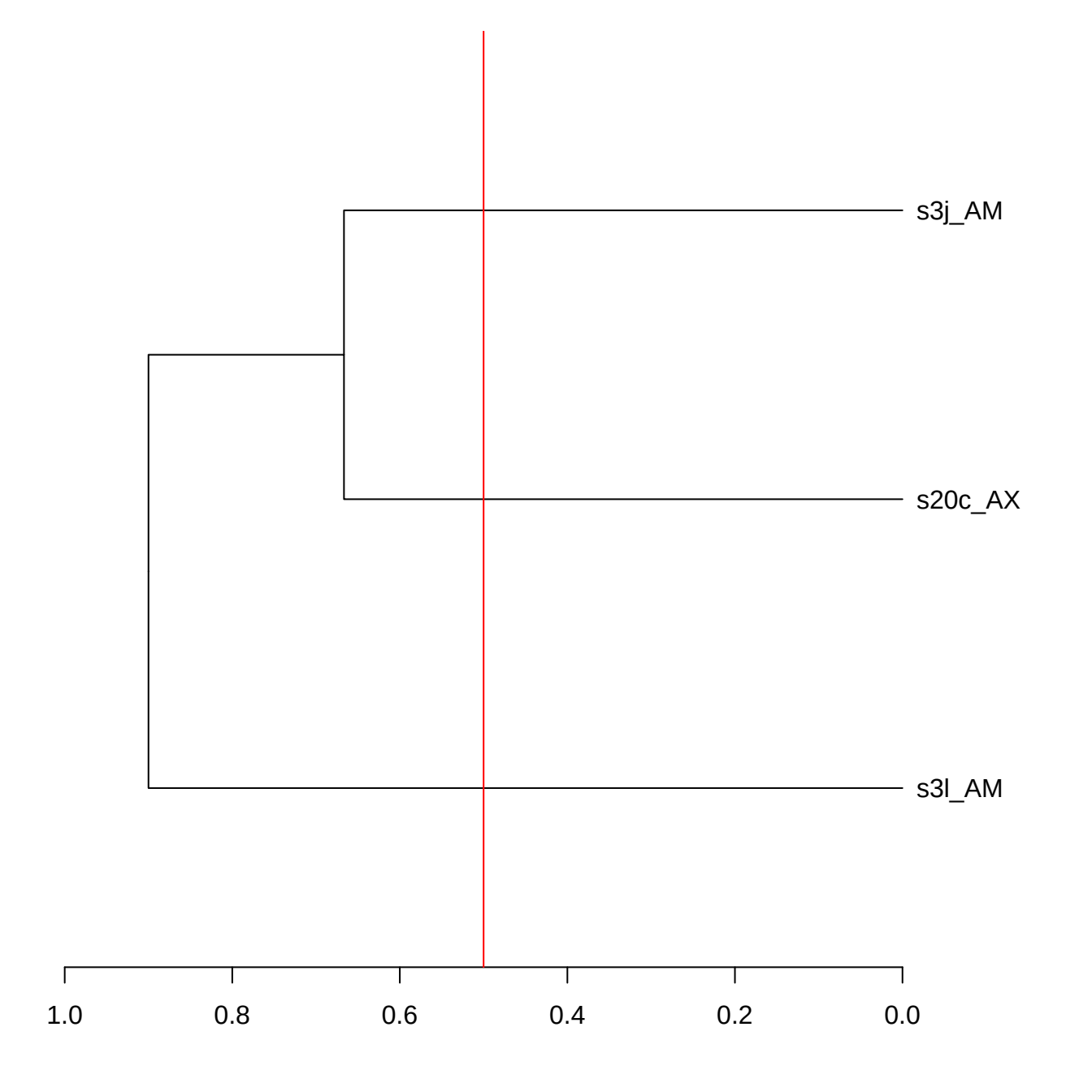
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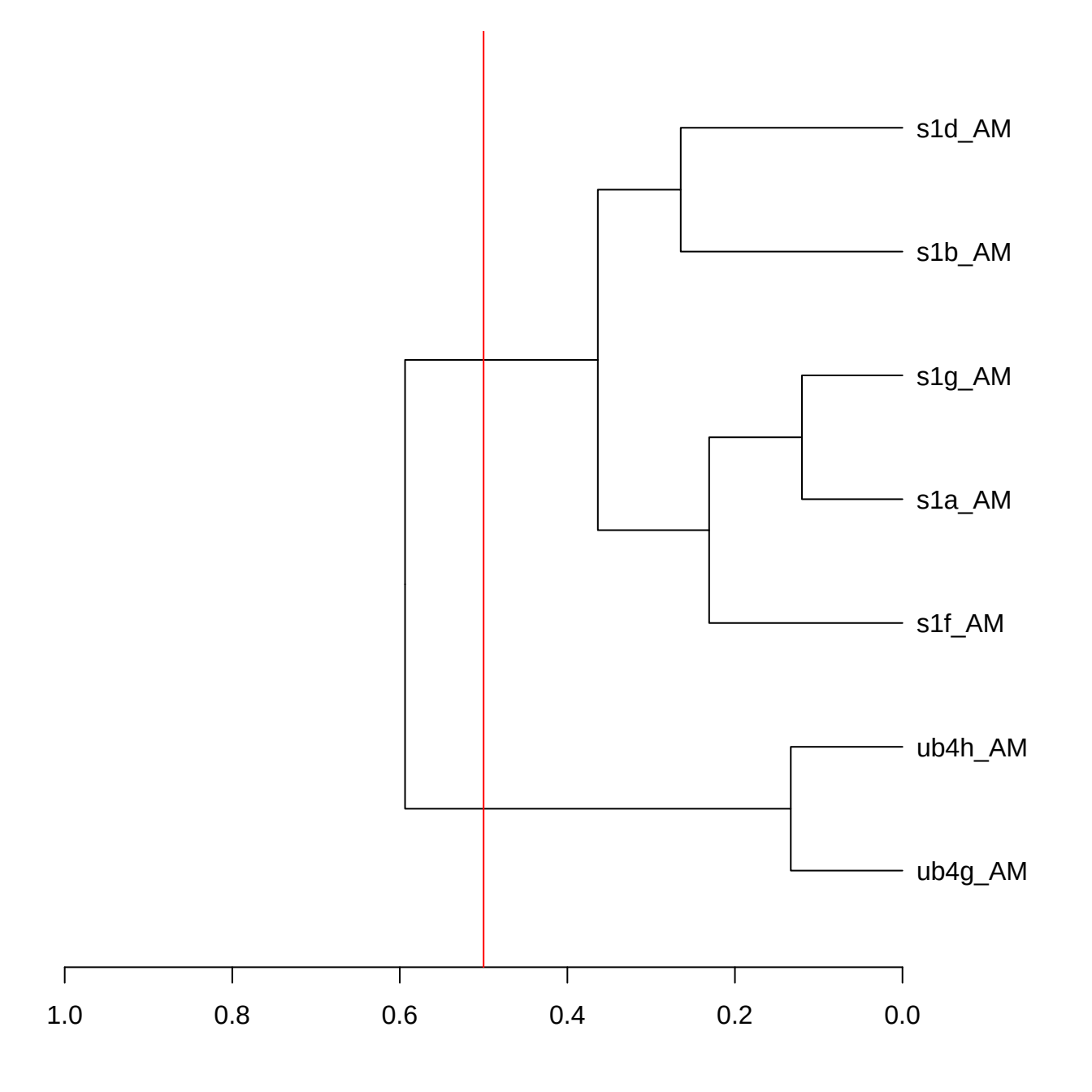
s20c_AX
s3l_AM
1.0
0.8
0.6
0.4
0.2
0.0


s1d_AM
s1b_AM
s1g_AM
s1a_AM
s1f_AM
ub4h_AM
ub4g_AM
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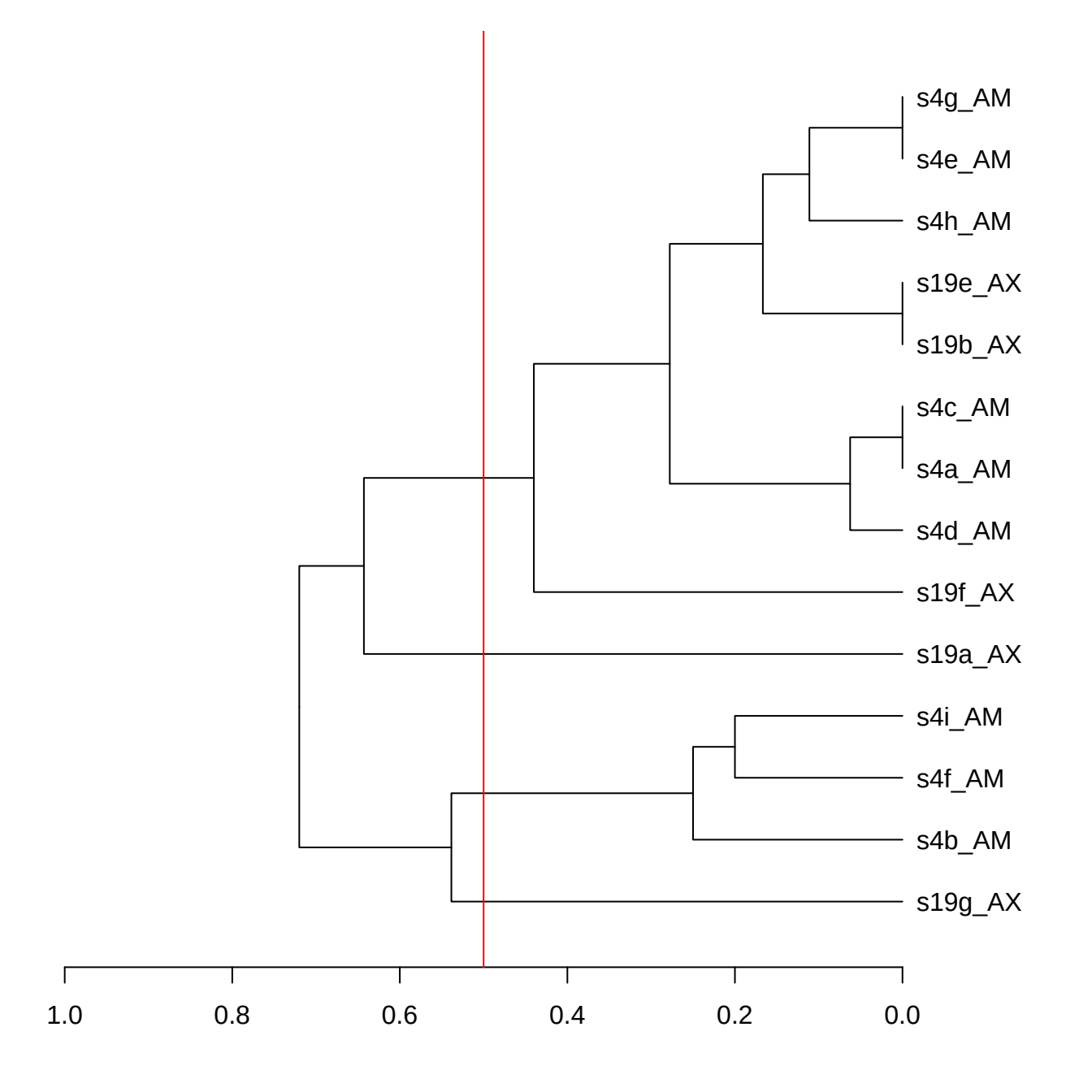
0.8
0.6
0.4
0.2
0.0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s4e_AM
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s4c_AM
s4a_AM
s4d_AM
s19f_AX
s19a_AX
s4i_AM
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s4b_AM
s19g_AX
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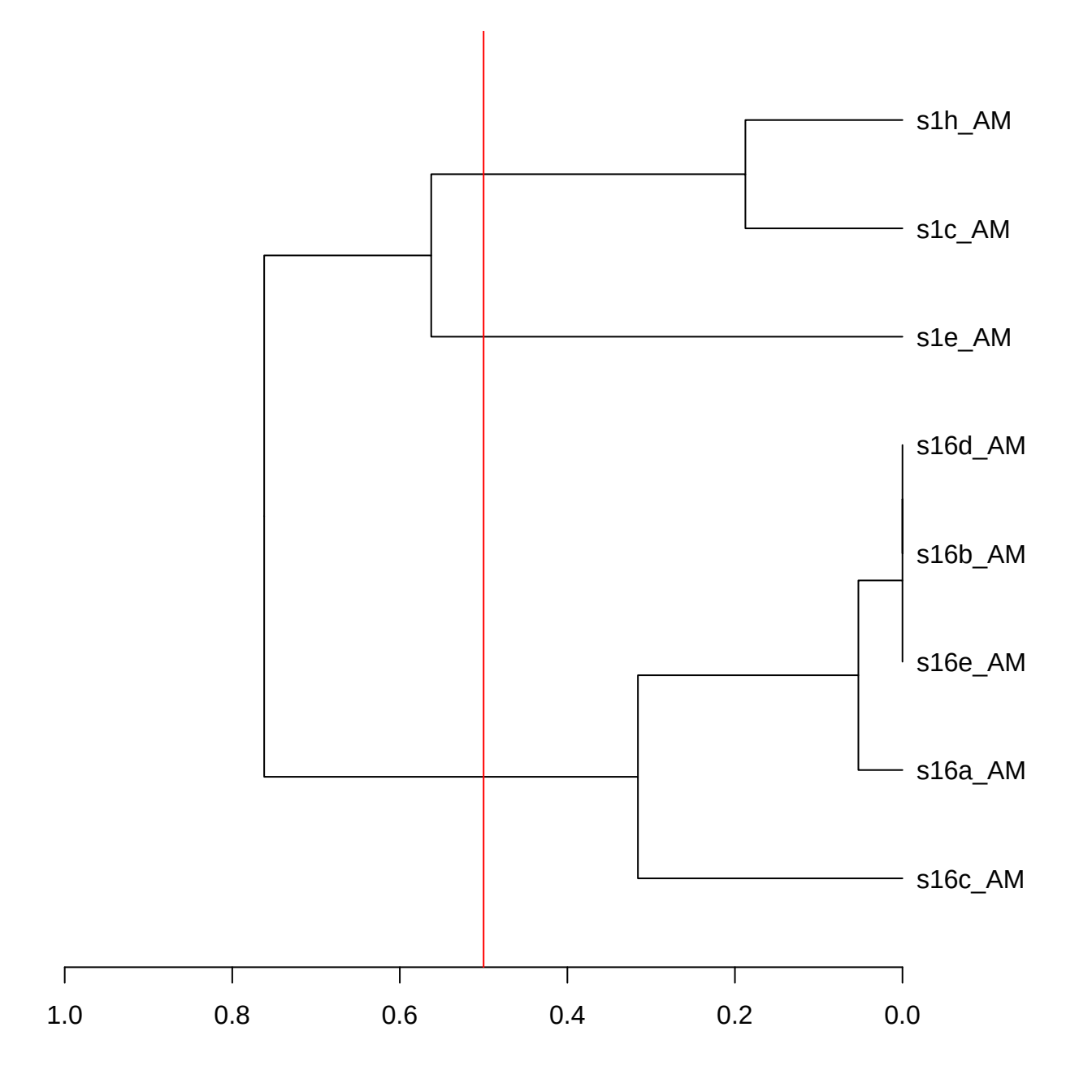
0.2
0.0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s1c_AM
s1e_AM
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s16a_AM
s16c_AM
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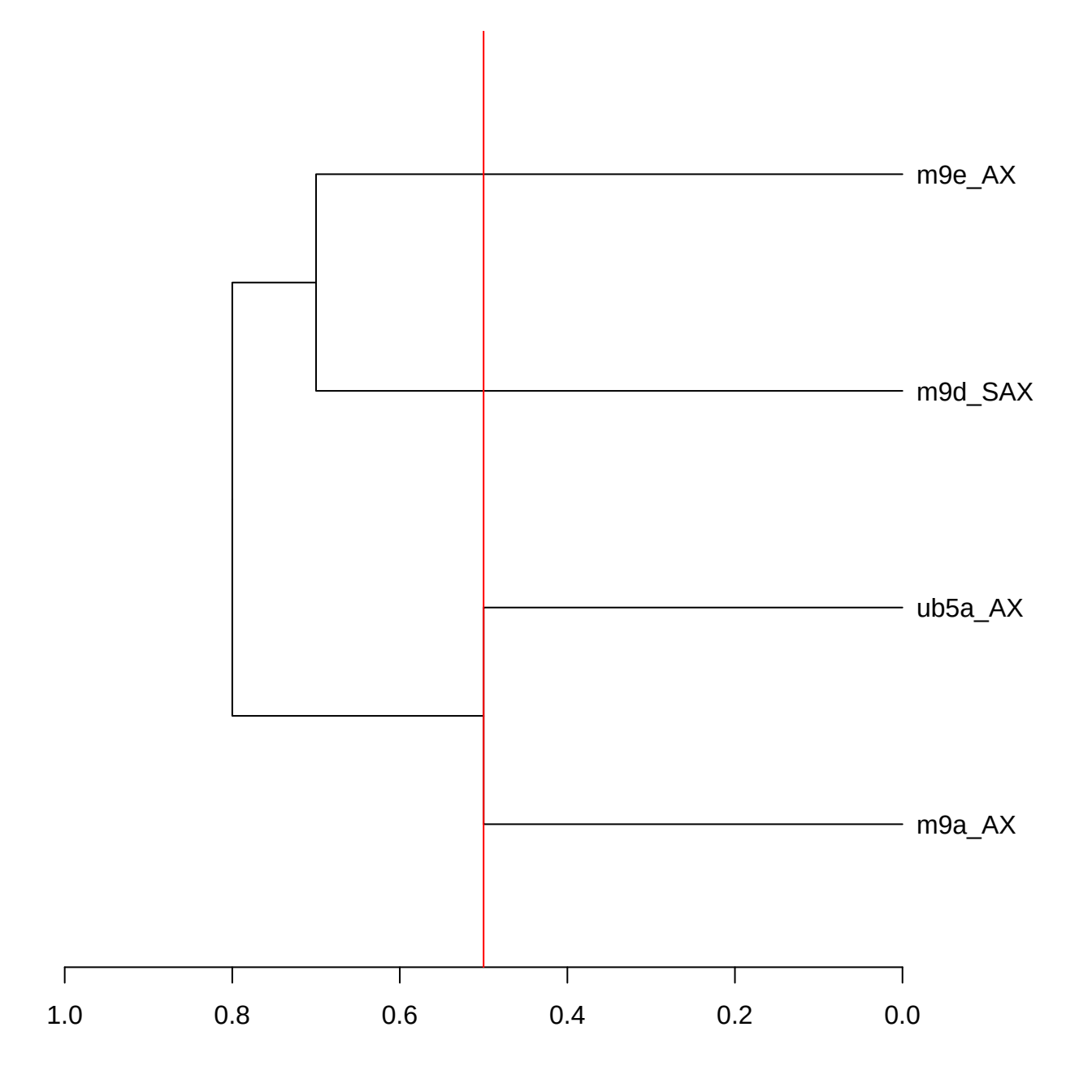
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ub5a_AX
m9a_AX
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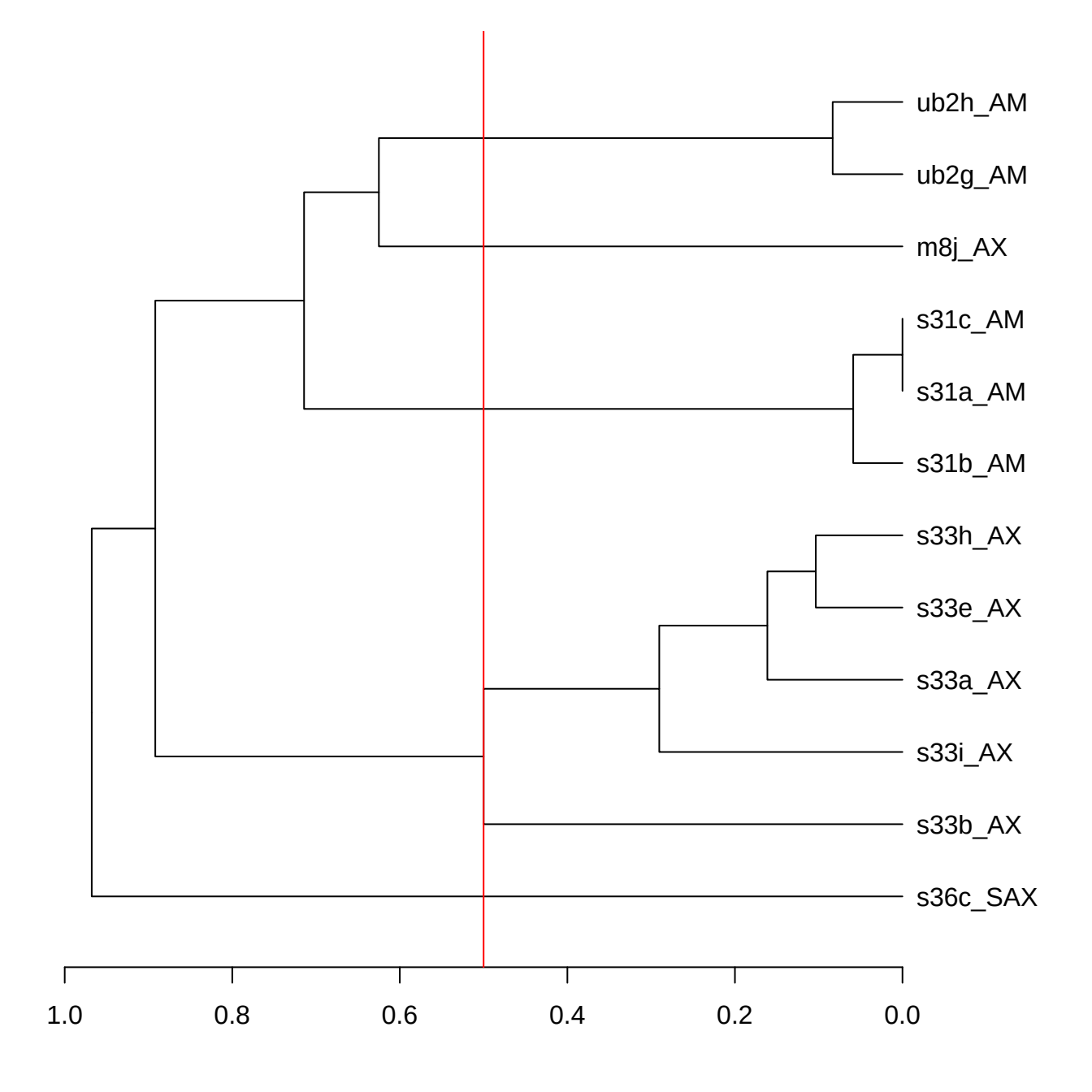
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ub2g_AM
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s31a_AM
s31b_AM
s33h_AX
s33e_AX
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0.4
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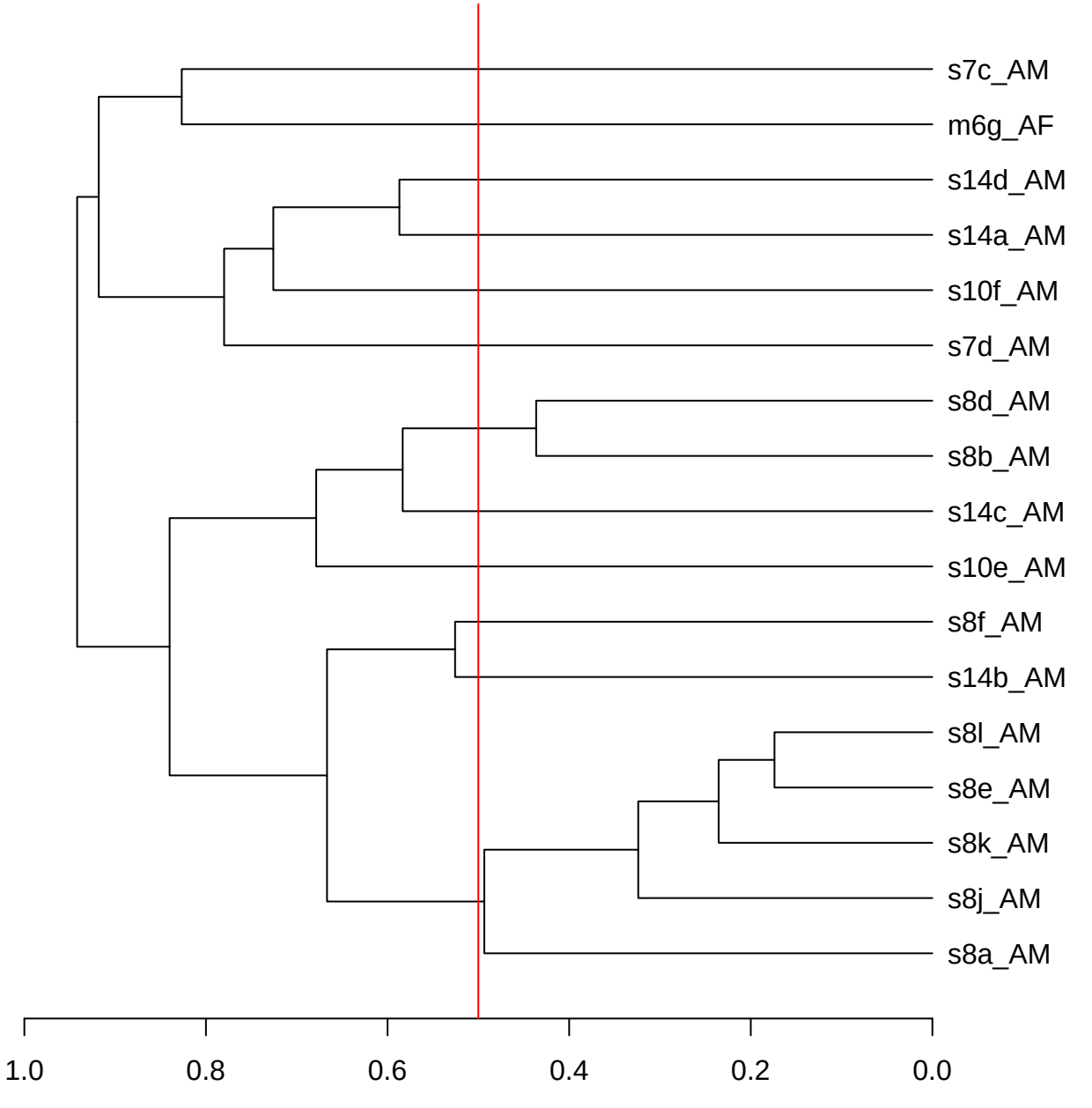
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s14d_AM
s14a_AM
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s8d_AM
s8b_AM
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s10e_AM
s8f_AM
s14b_AM
s8l_AM
s8e_AM
s8k_AM
s8j_AM
s8a_AM
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0.4
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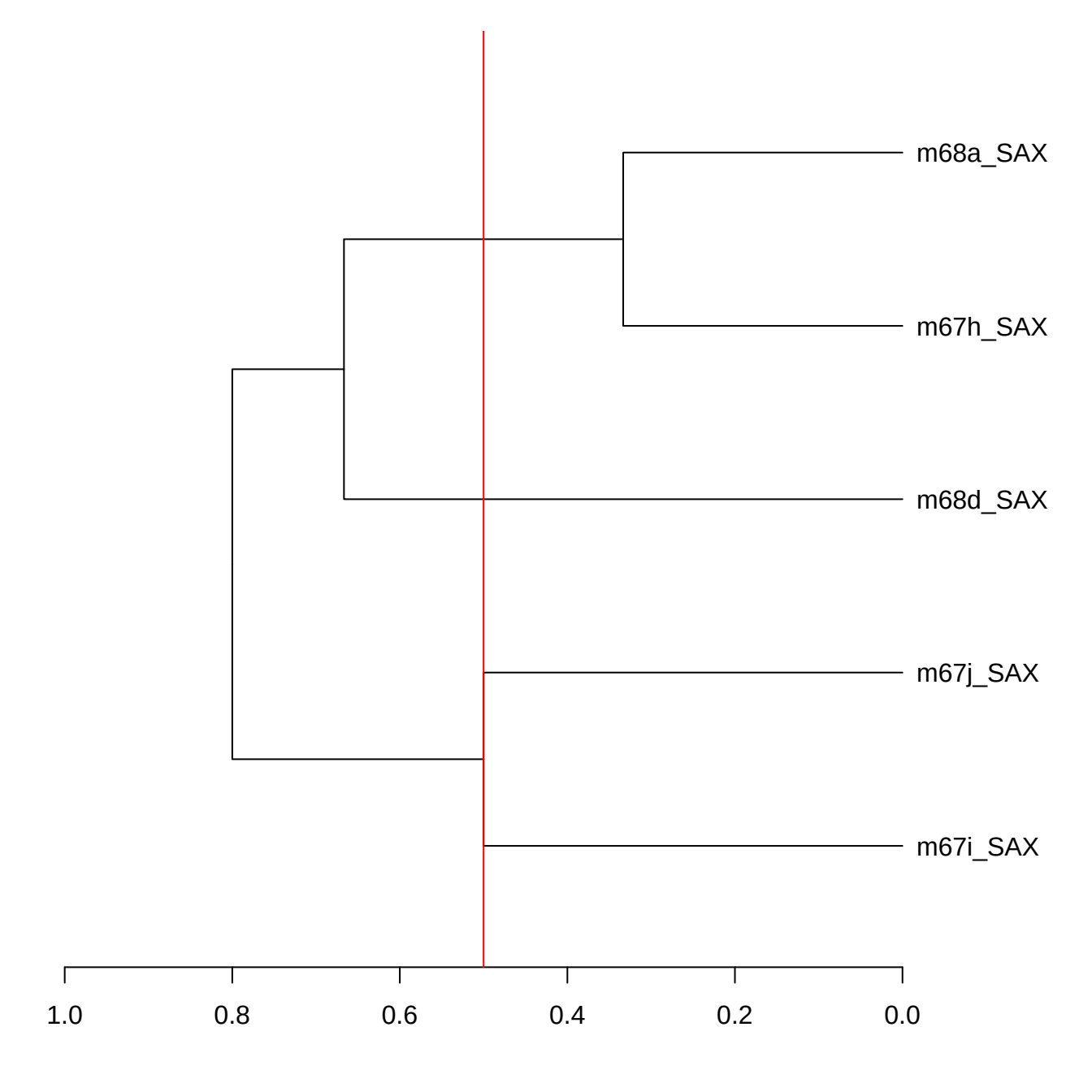
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m68d_SAX
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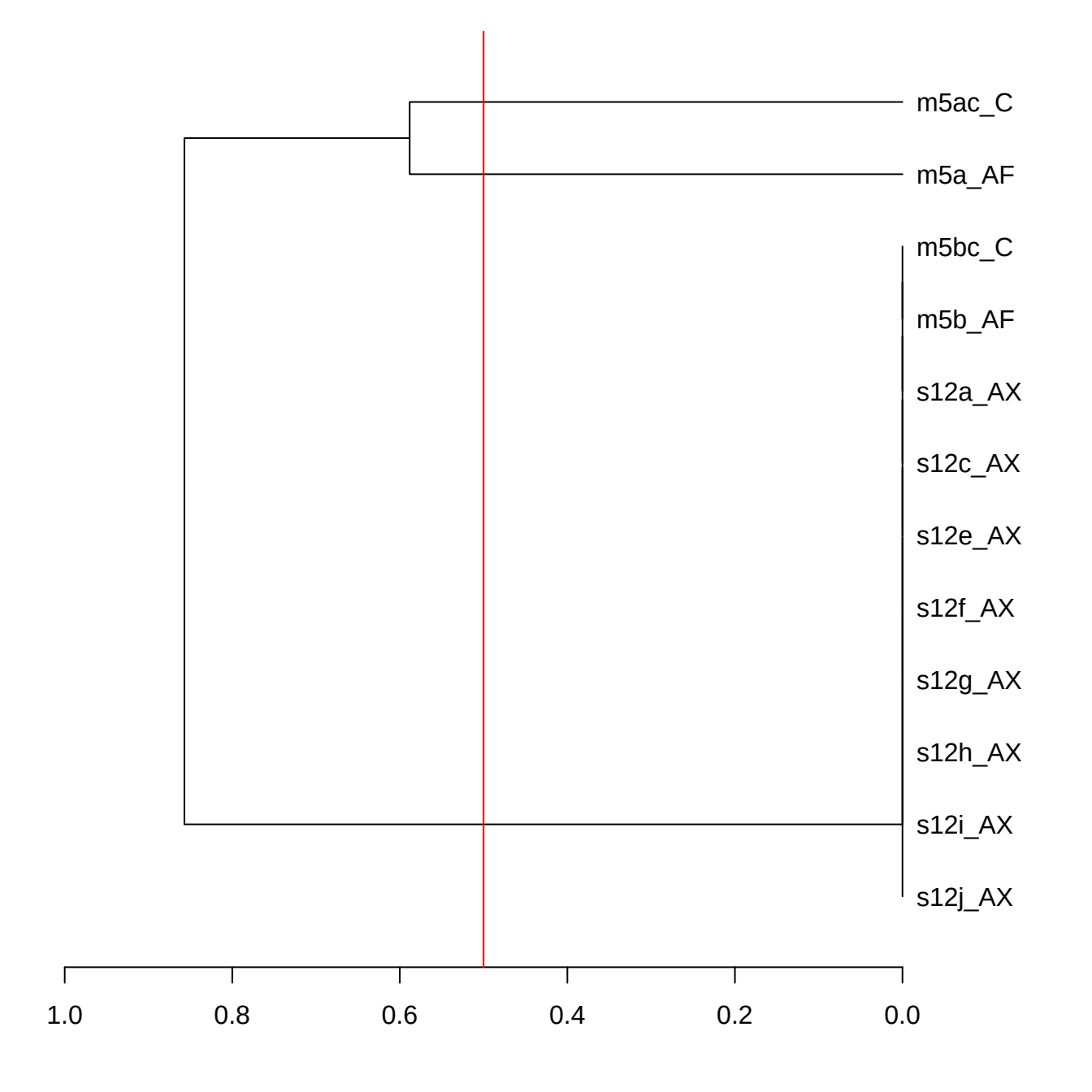
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s12c_AX
s12e_AX
s12f_AX
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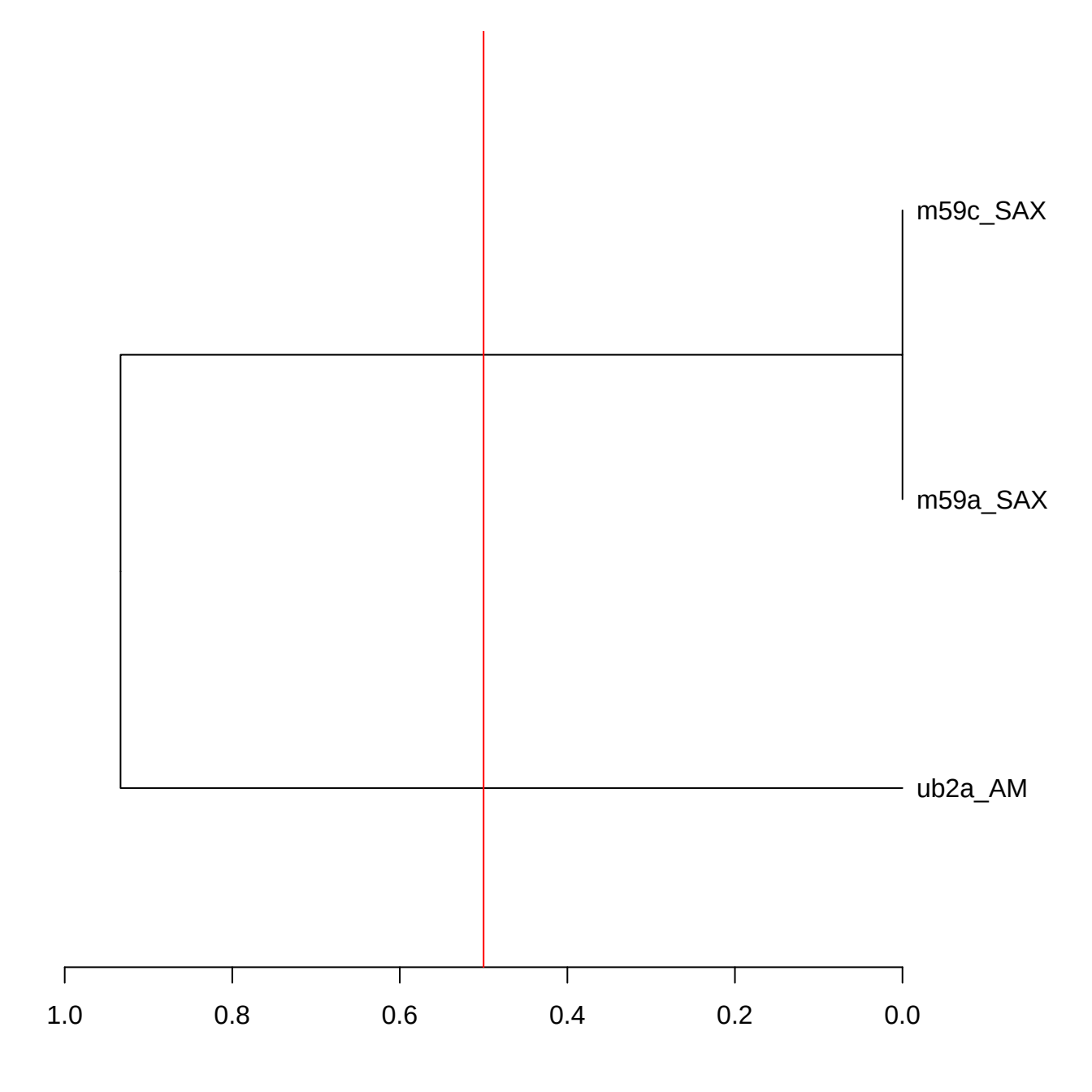
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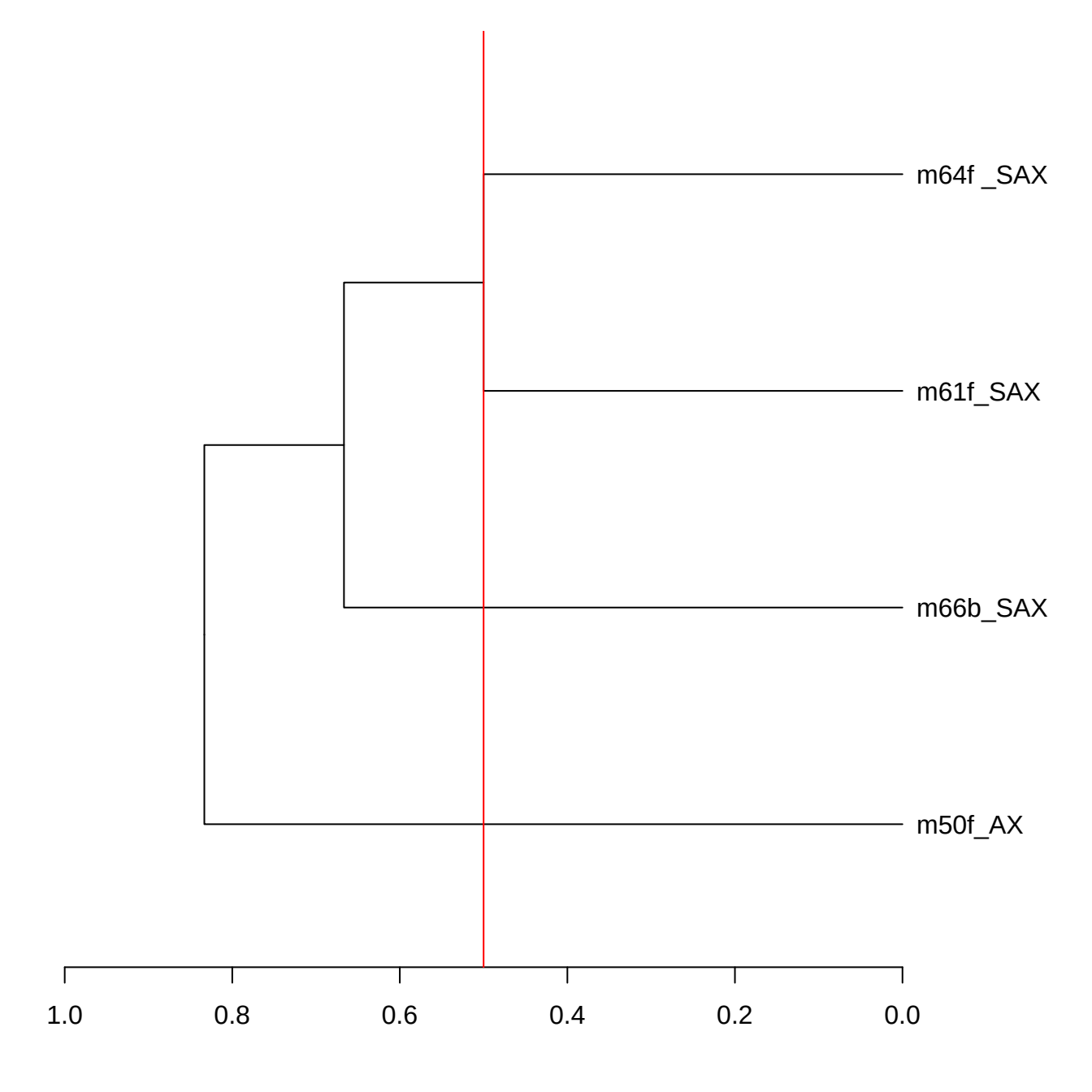
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m61f_SAX
m66b_SAX
m50f_AX
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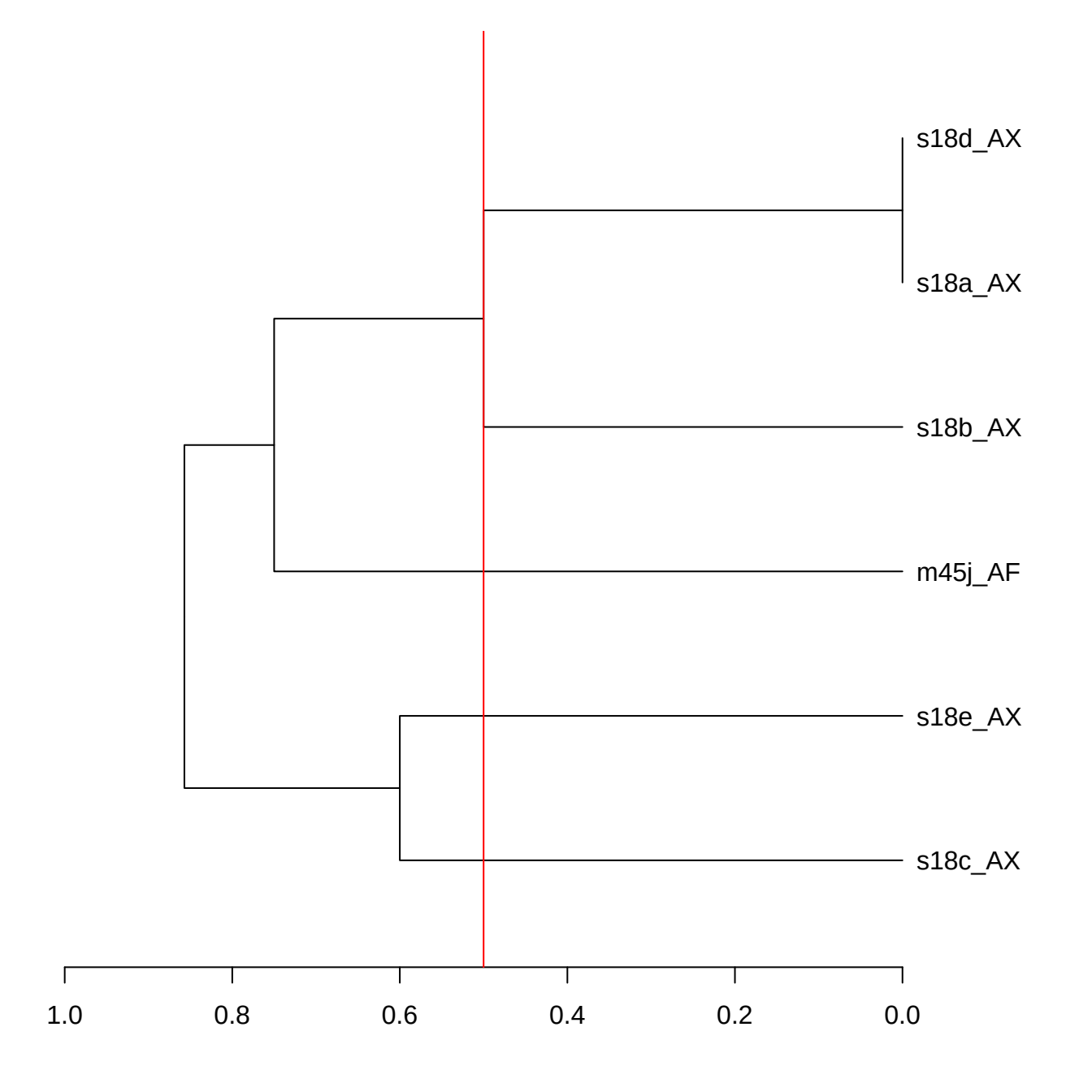
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s18b_AX
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s18e_AX
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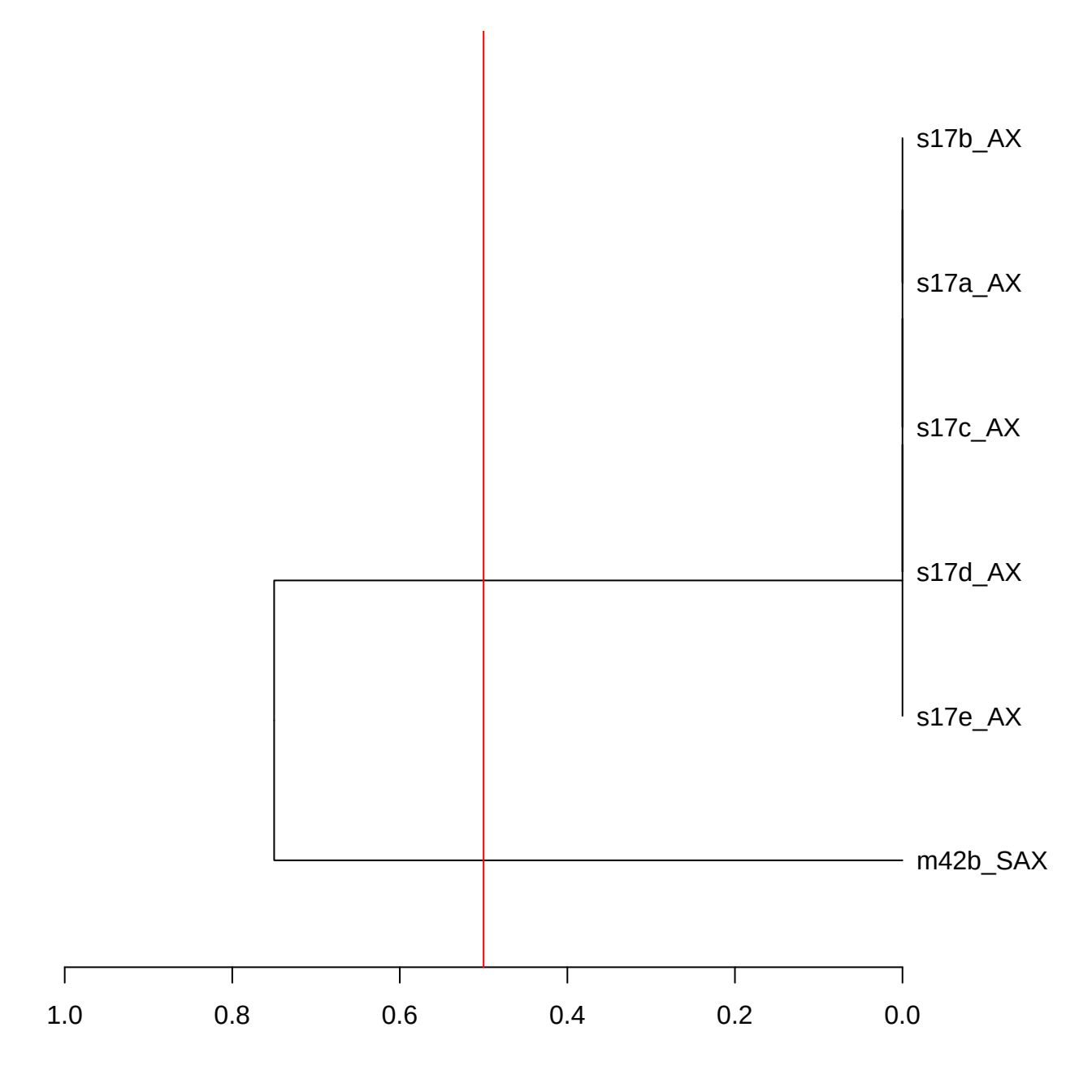
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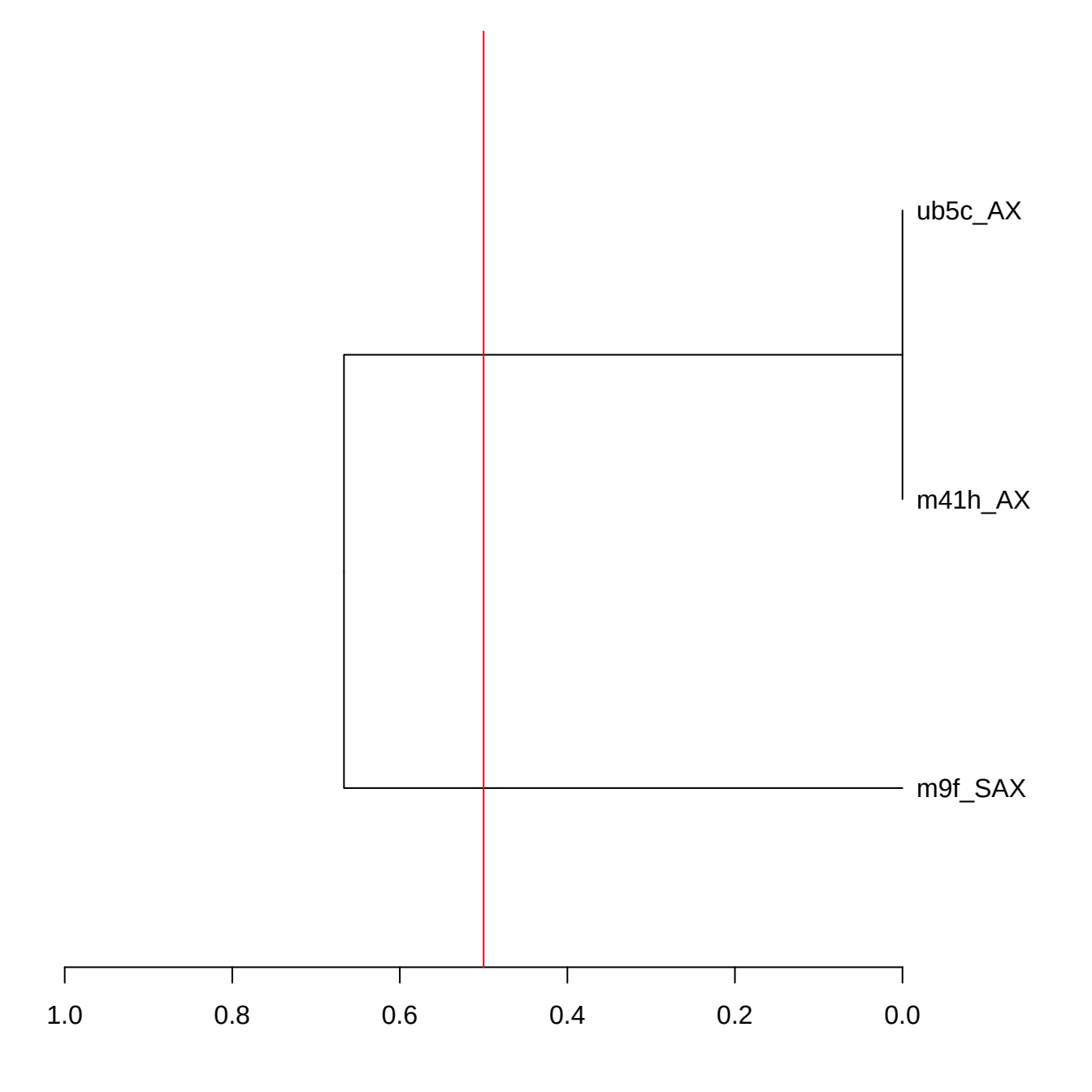
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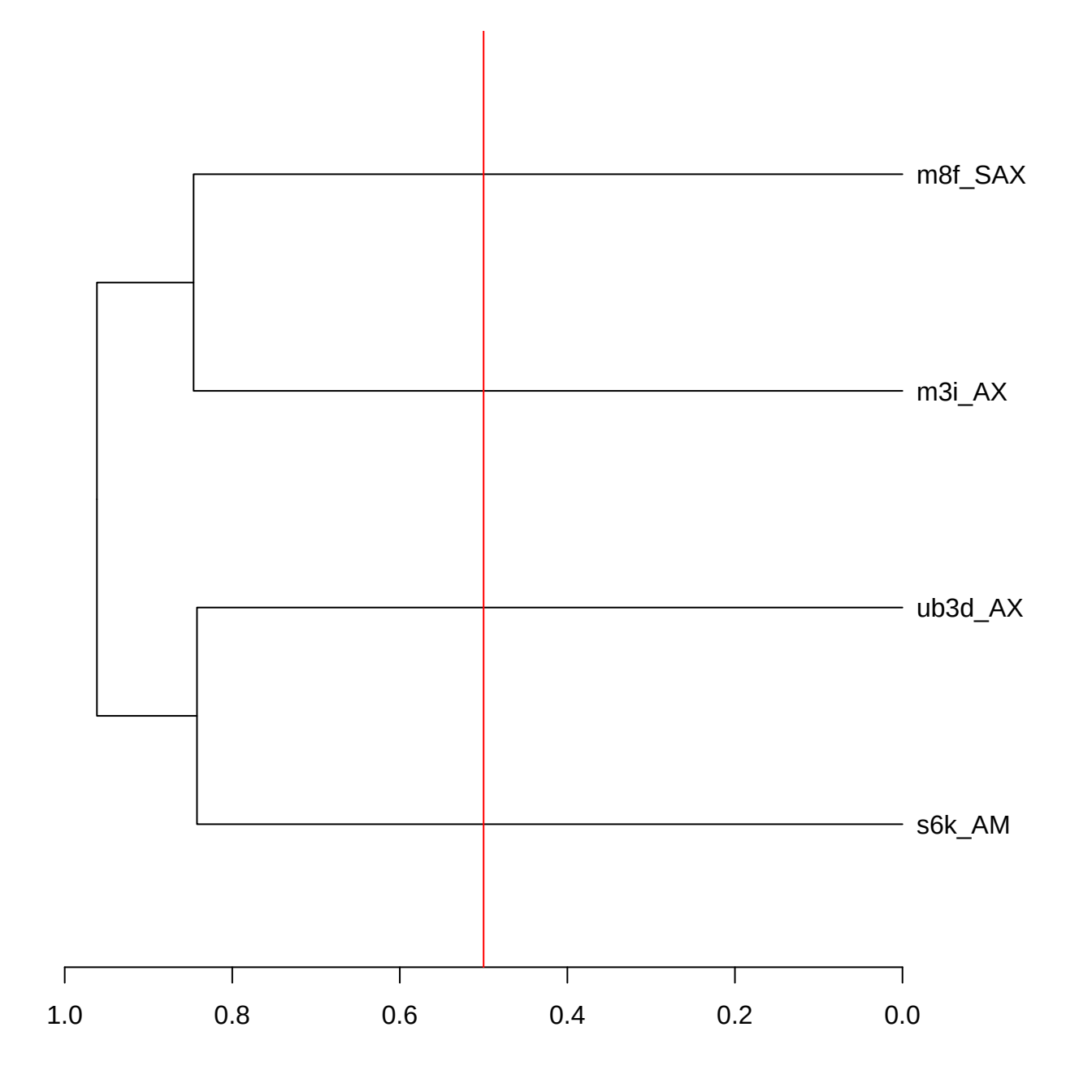
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ub3d_AX
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0.2
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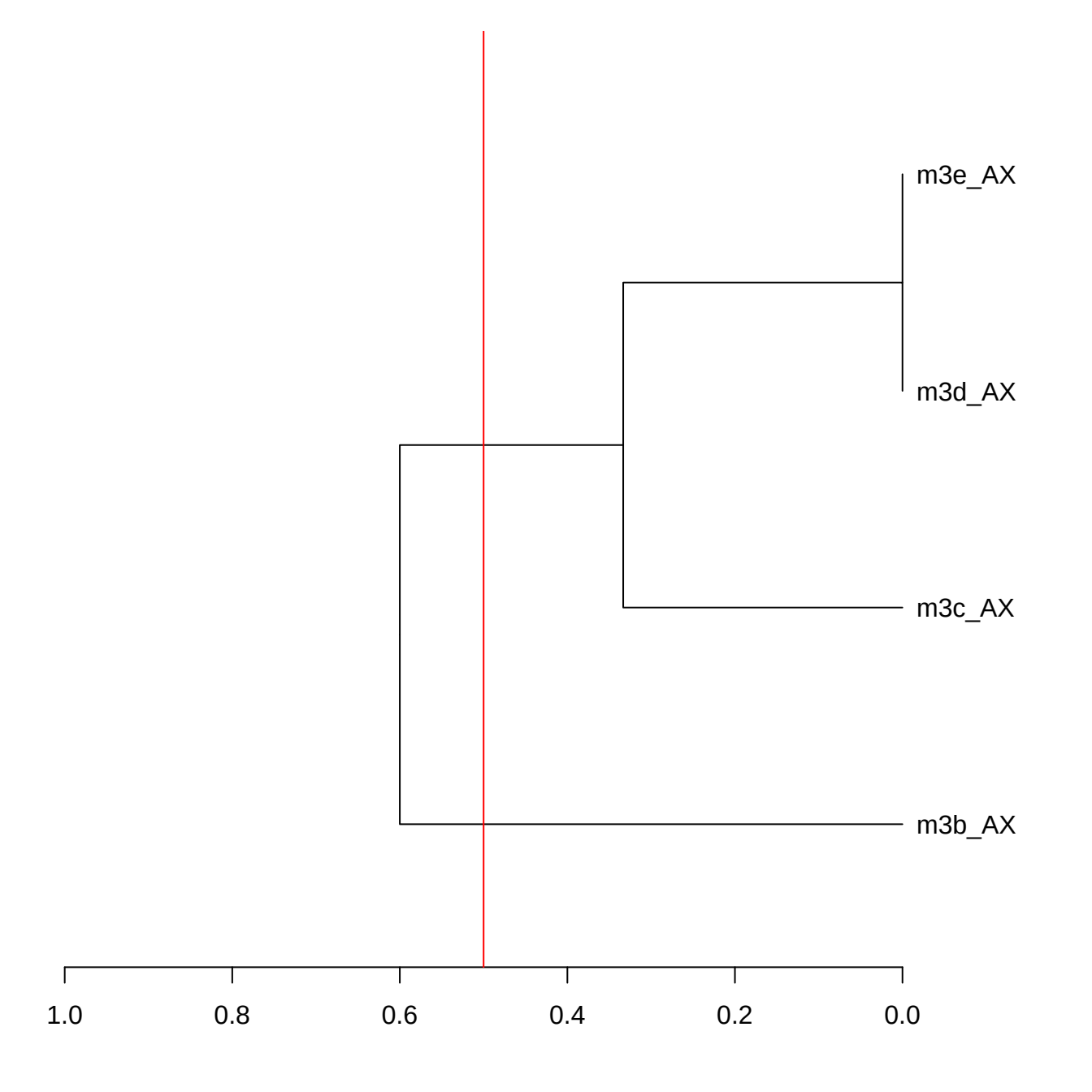
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m3d_AX
m3c_AX
m3b_AX
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0.4
0.2
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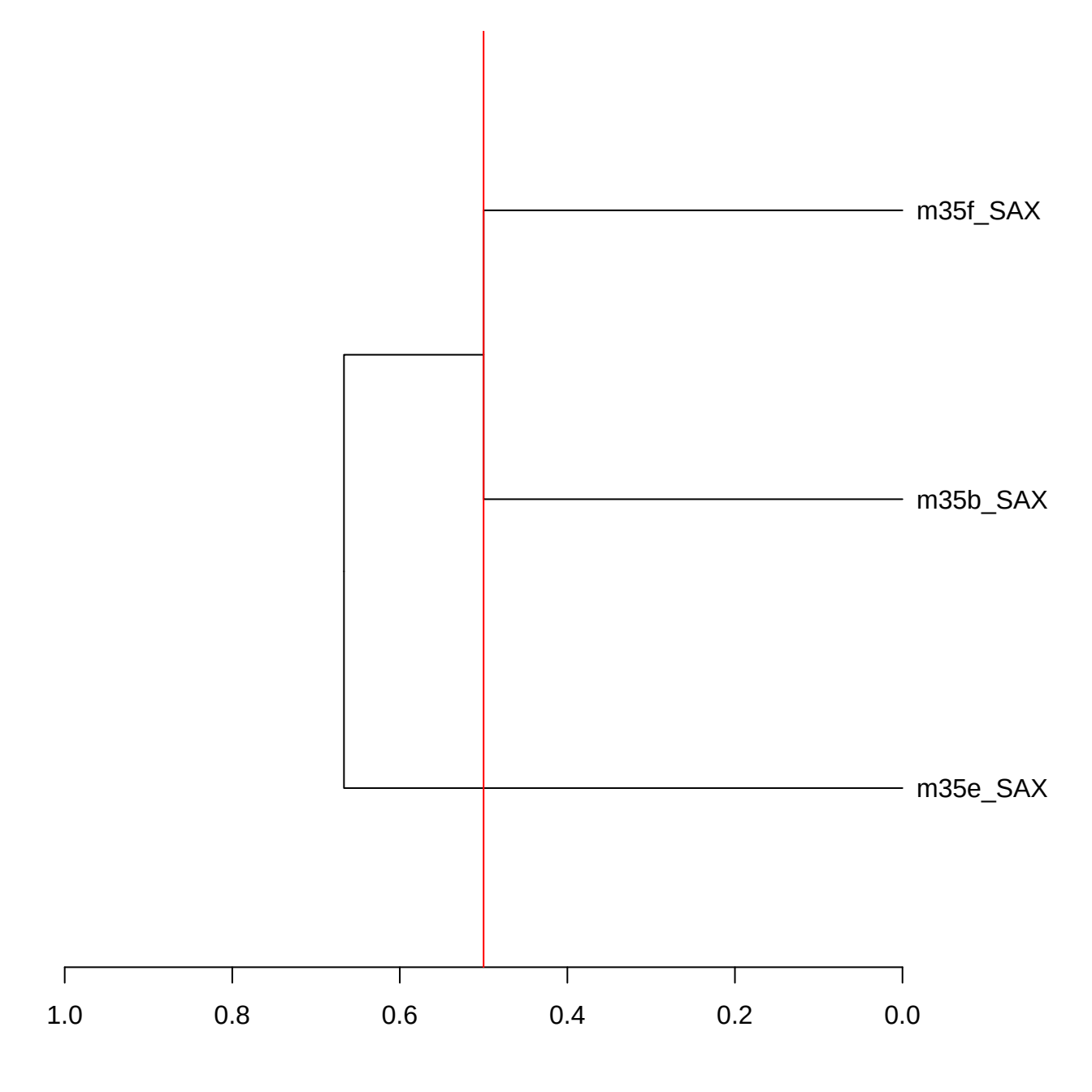
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m35e_SAX
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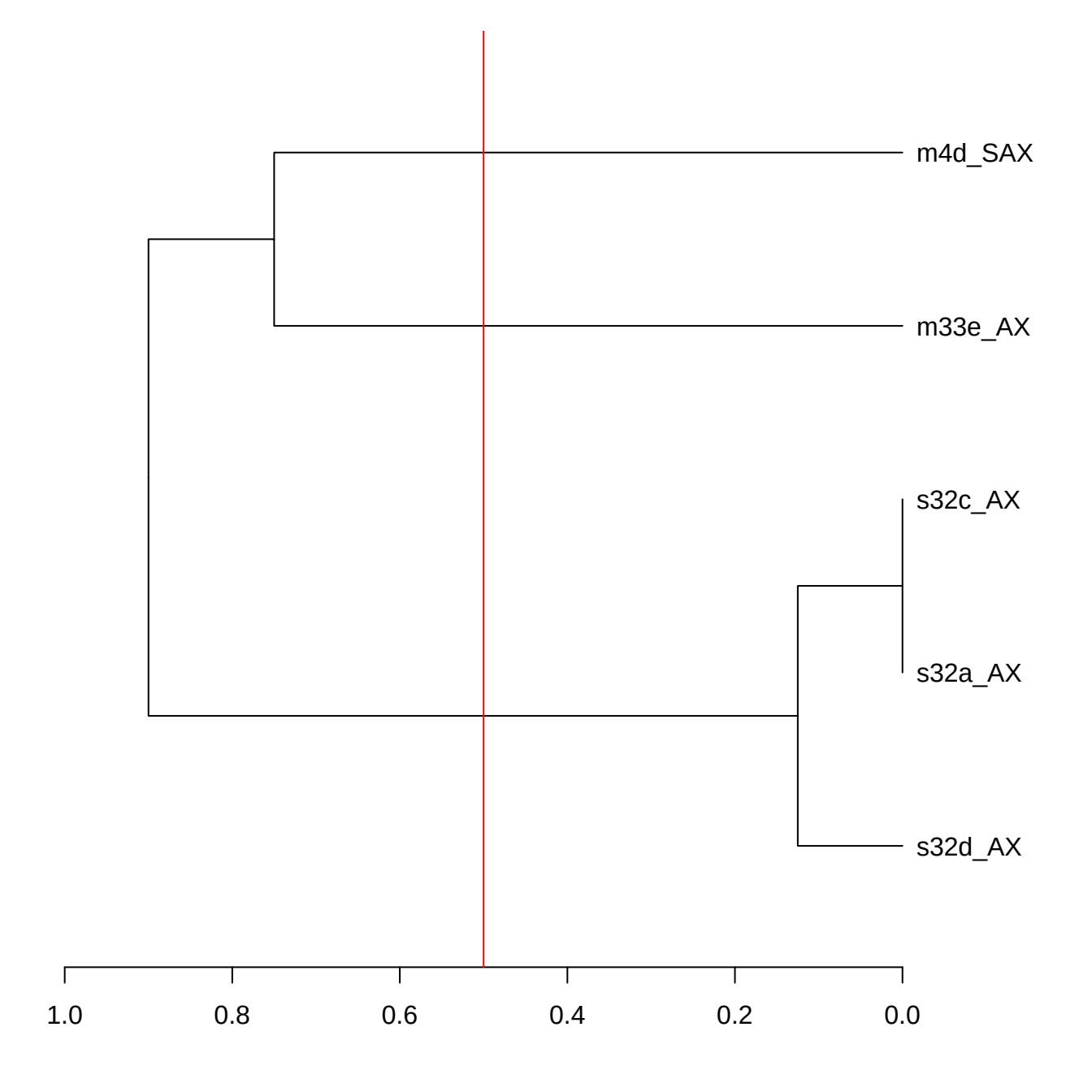
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m33e_AX
s32c_AX
s32a_AX
s32d_AX
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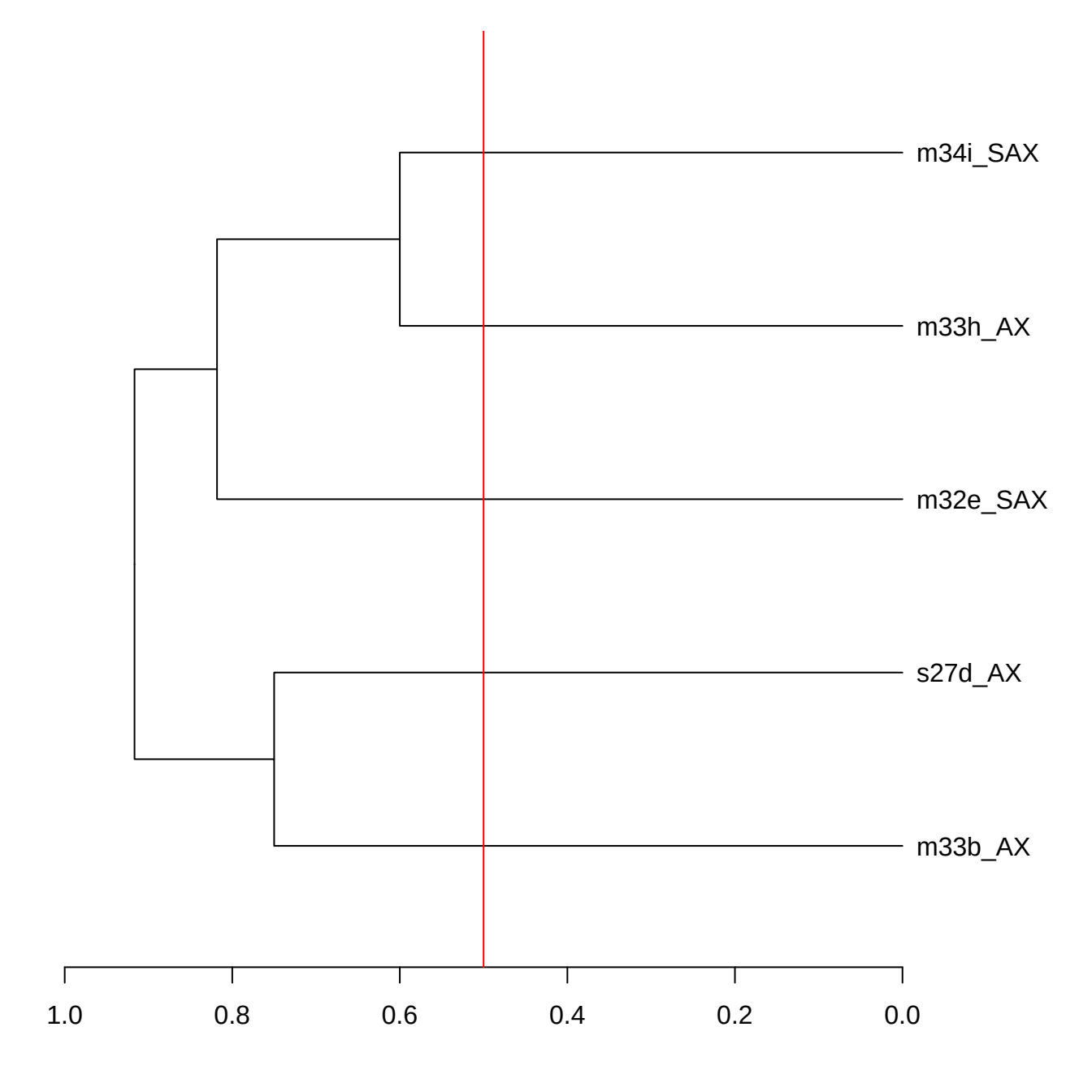
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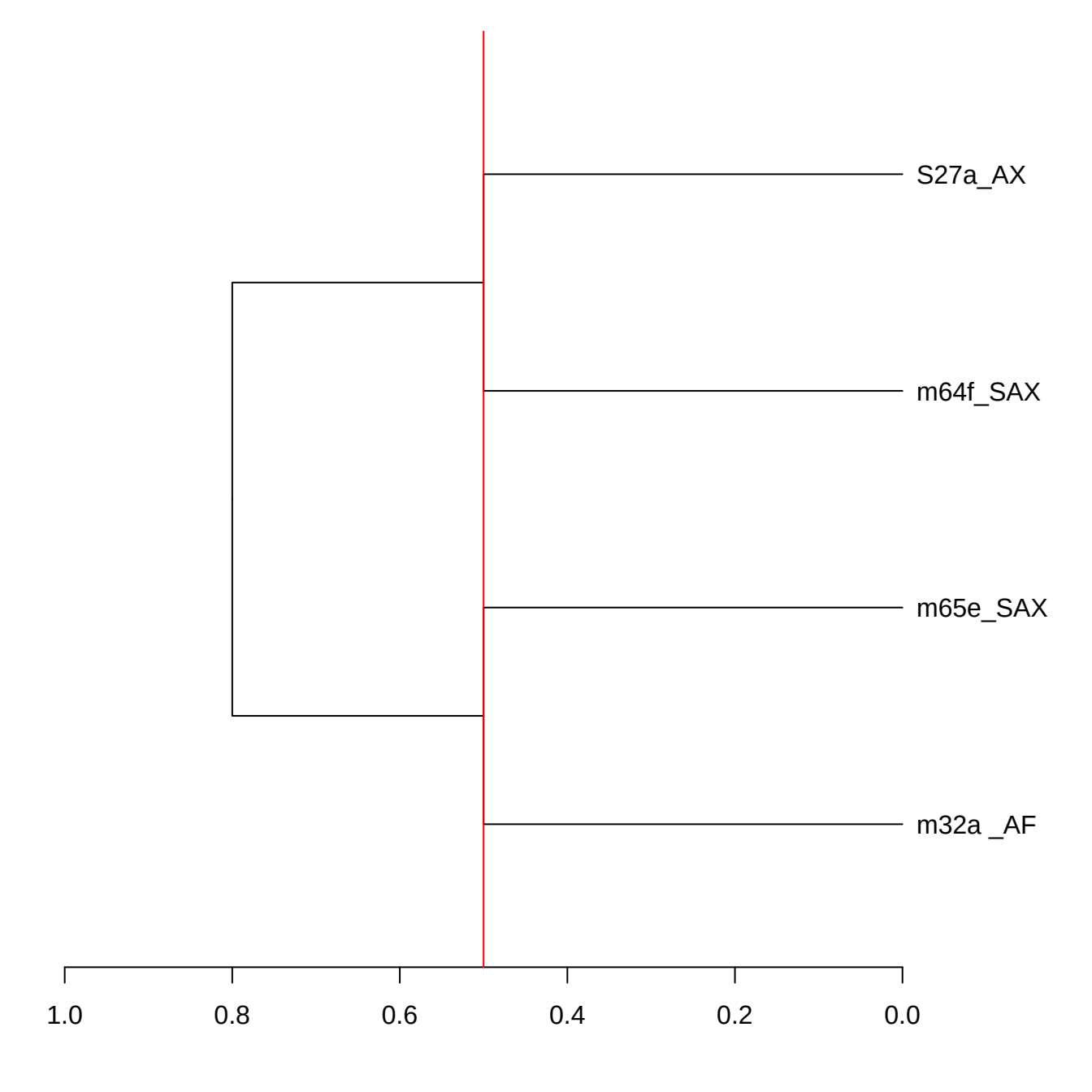
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m65e_SAX
m32a _AF
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0.6
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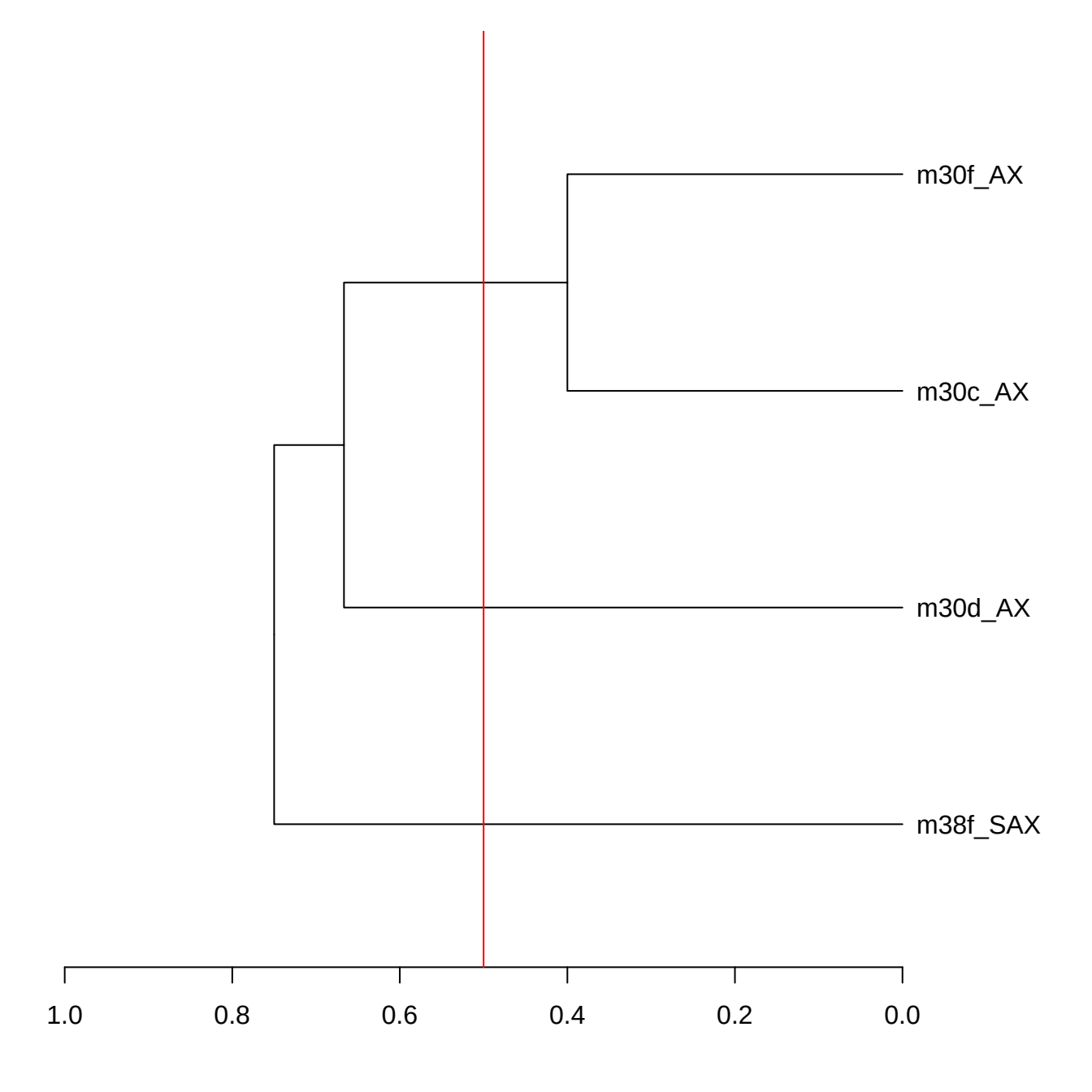
0.0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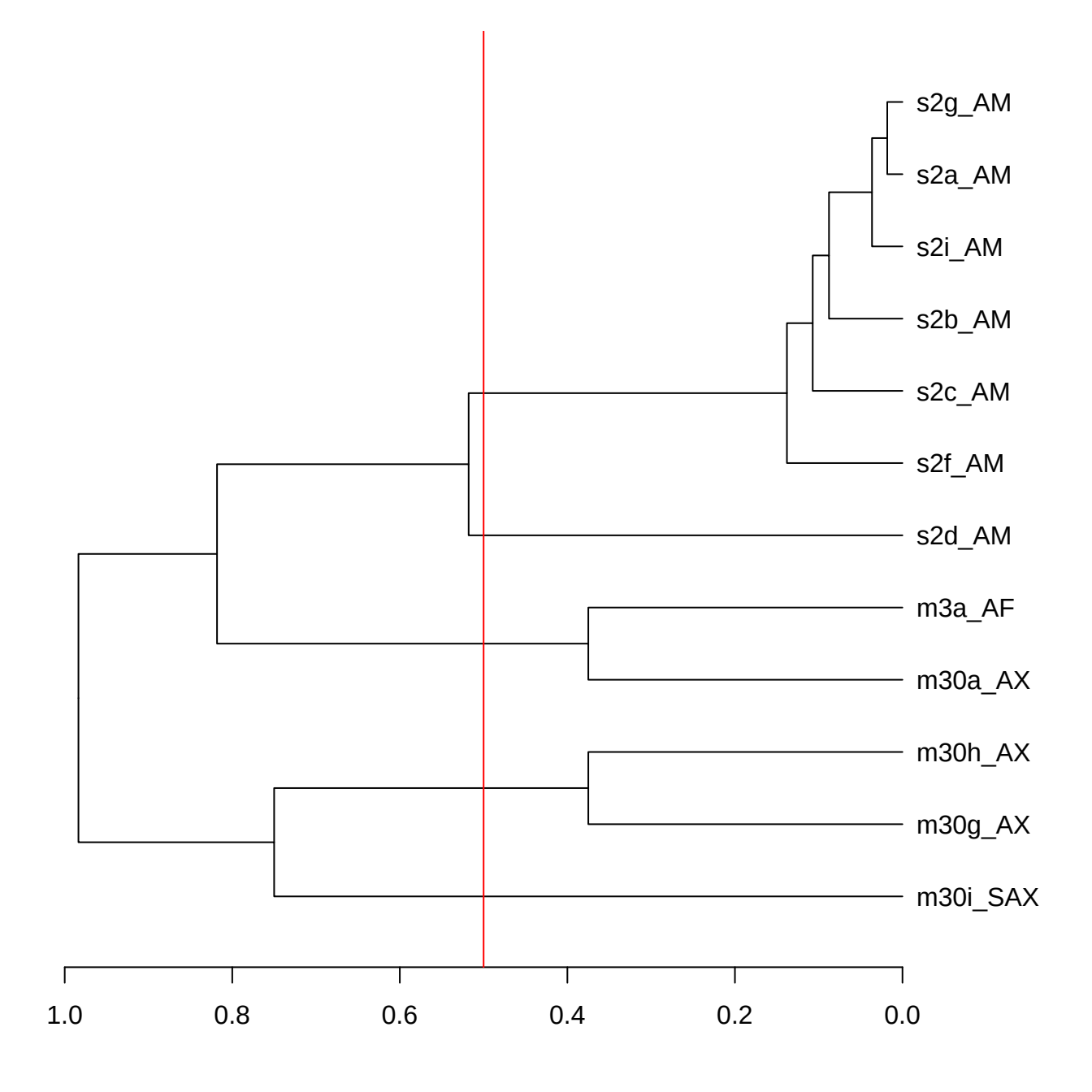
m30c_AX
m30d_AX
m38f_SAX
1.0
0.8
0.6
0.4
0.2
0.0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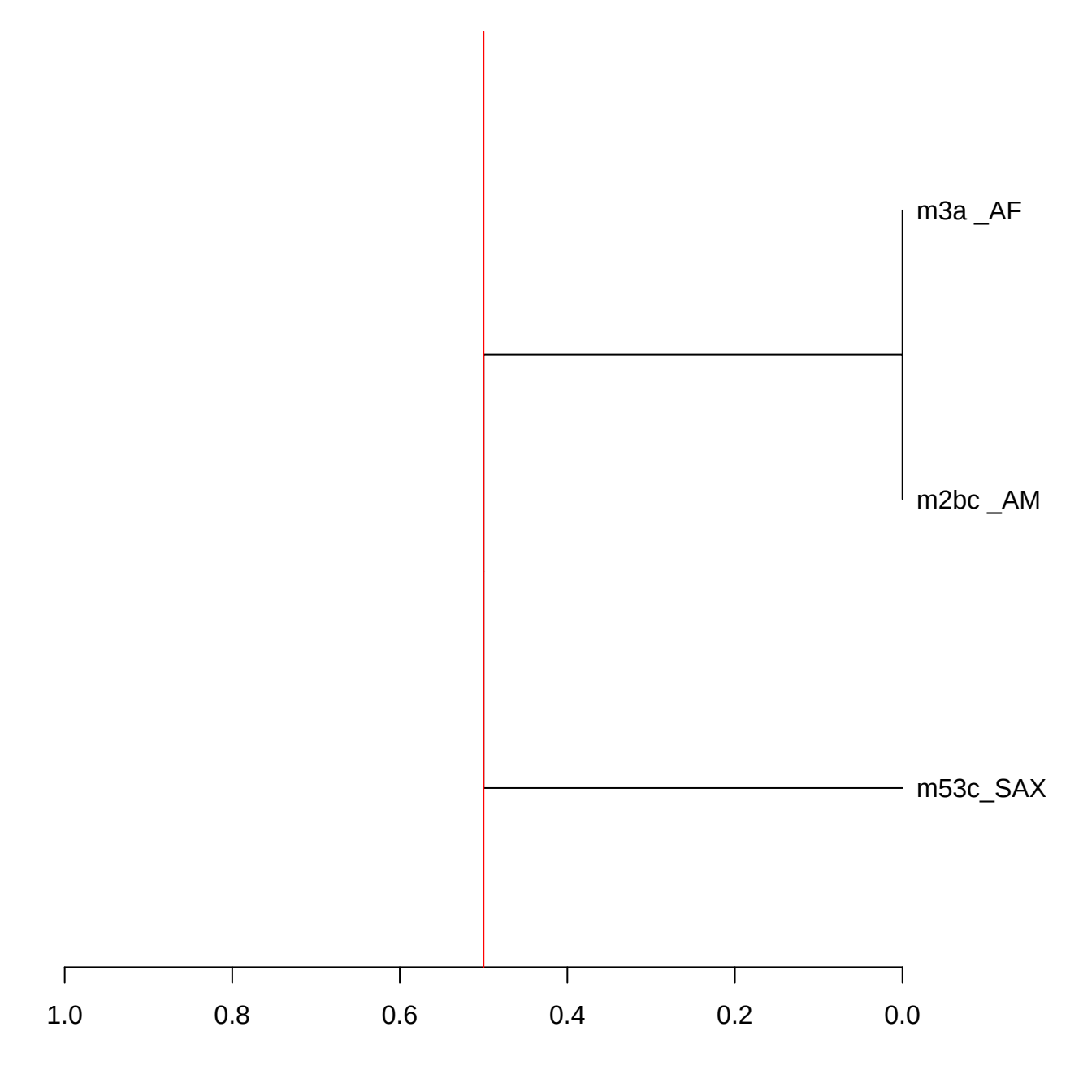
s2a_AM
s2i_AM
s2b_AM
s2c_AM
s2f_AM
s2d_AM
m3a_AF
m30a_AX
m30h_AX
m30g_AX
m30i_SAX
1.0
0.8
0.6
0.4
0.2
0.0


m3a _AF
m2bc _AM
m53c_SAX
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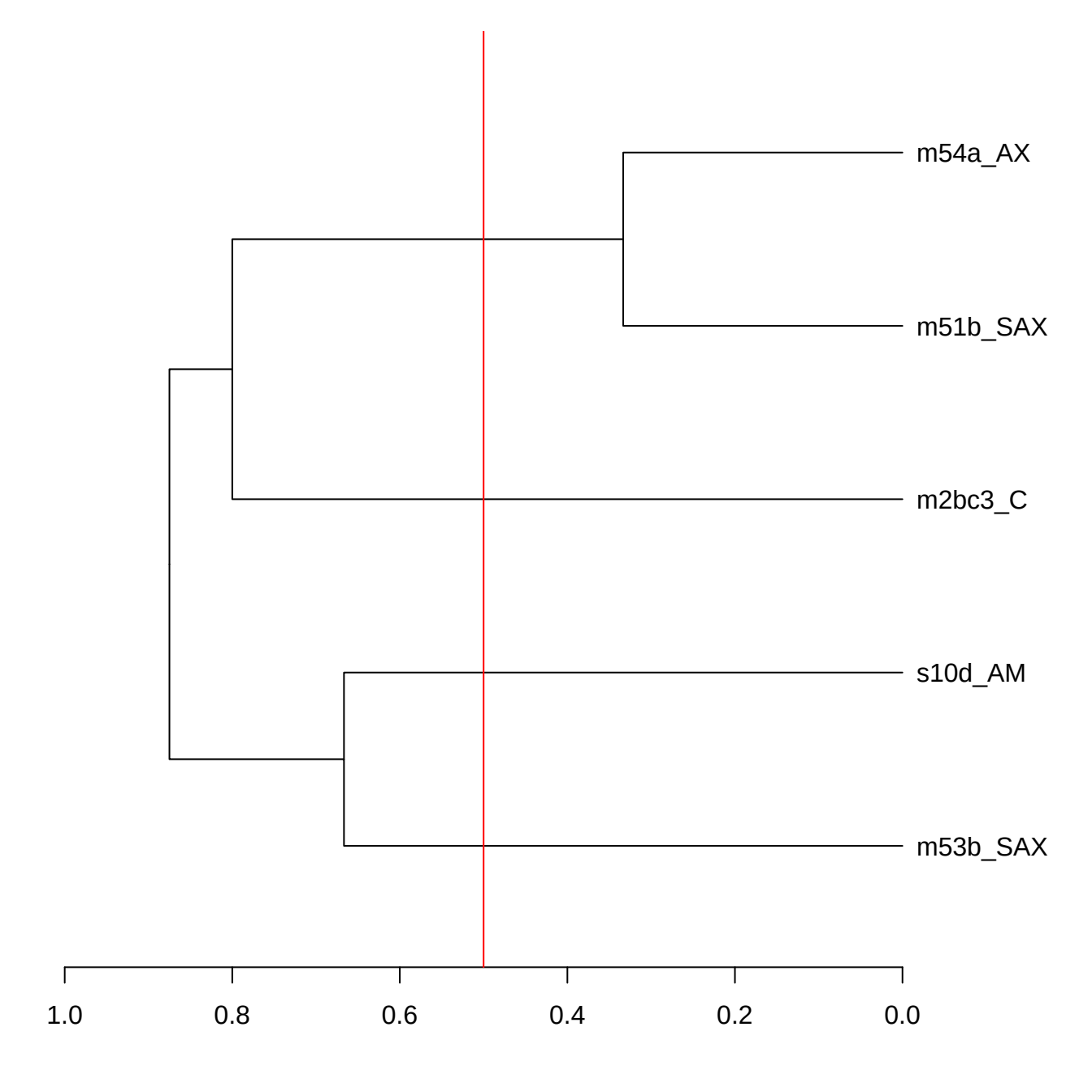
0.8
0.6
0.4
0.2
0.0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m51b_SAX
m2bc3_C
s10d_AM
m53b_SAX
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0.6
0.4
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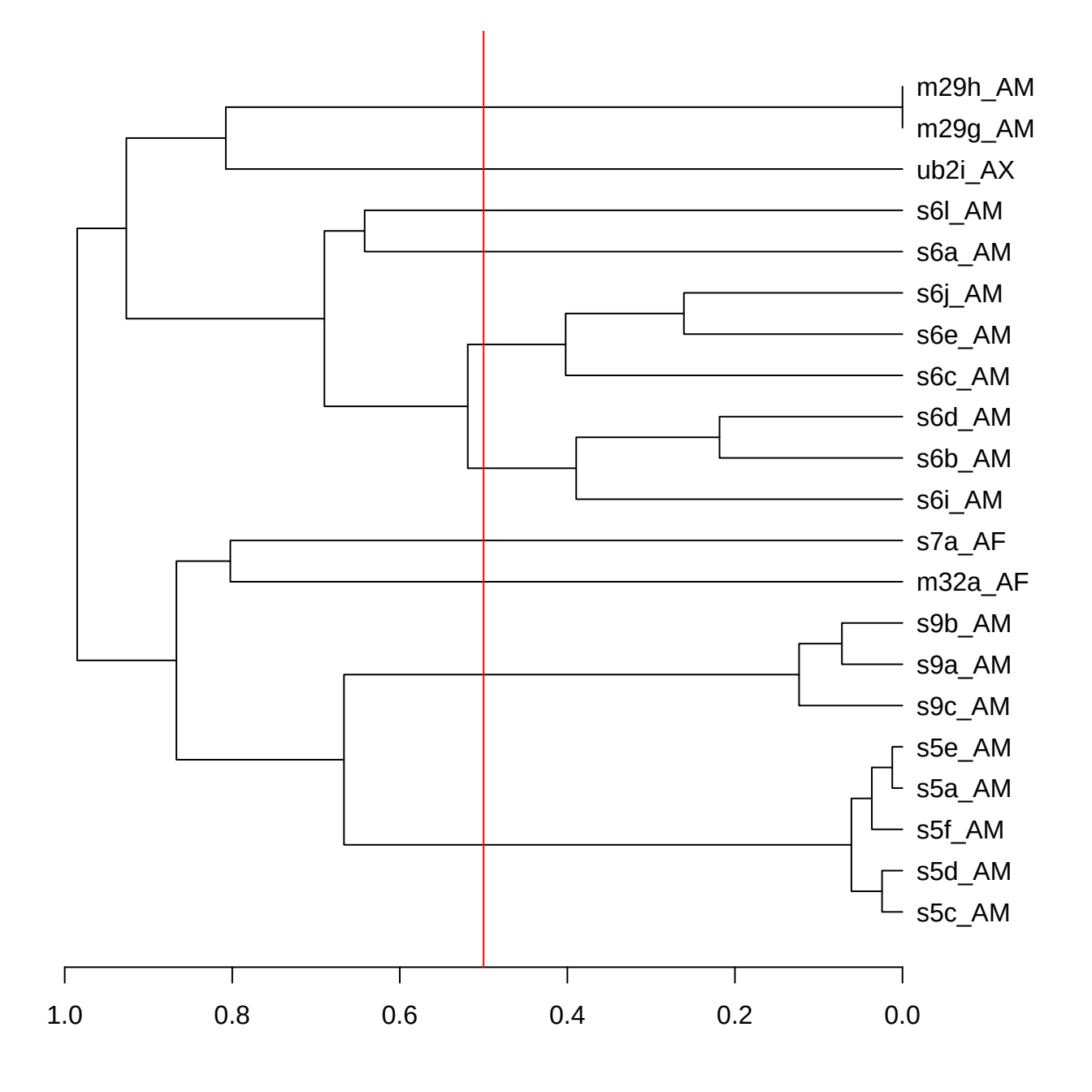
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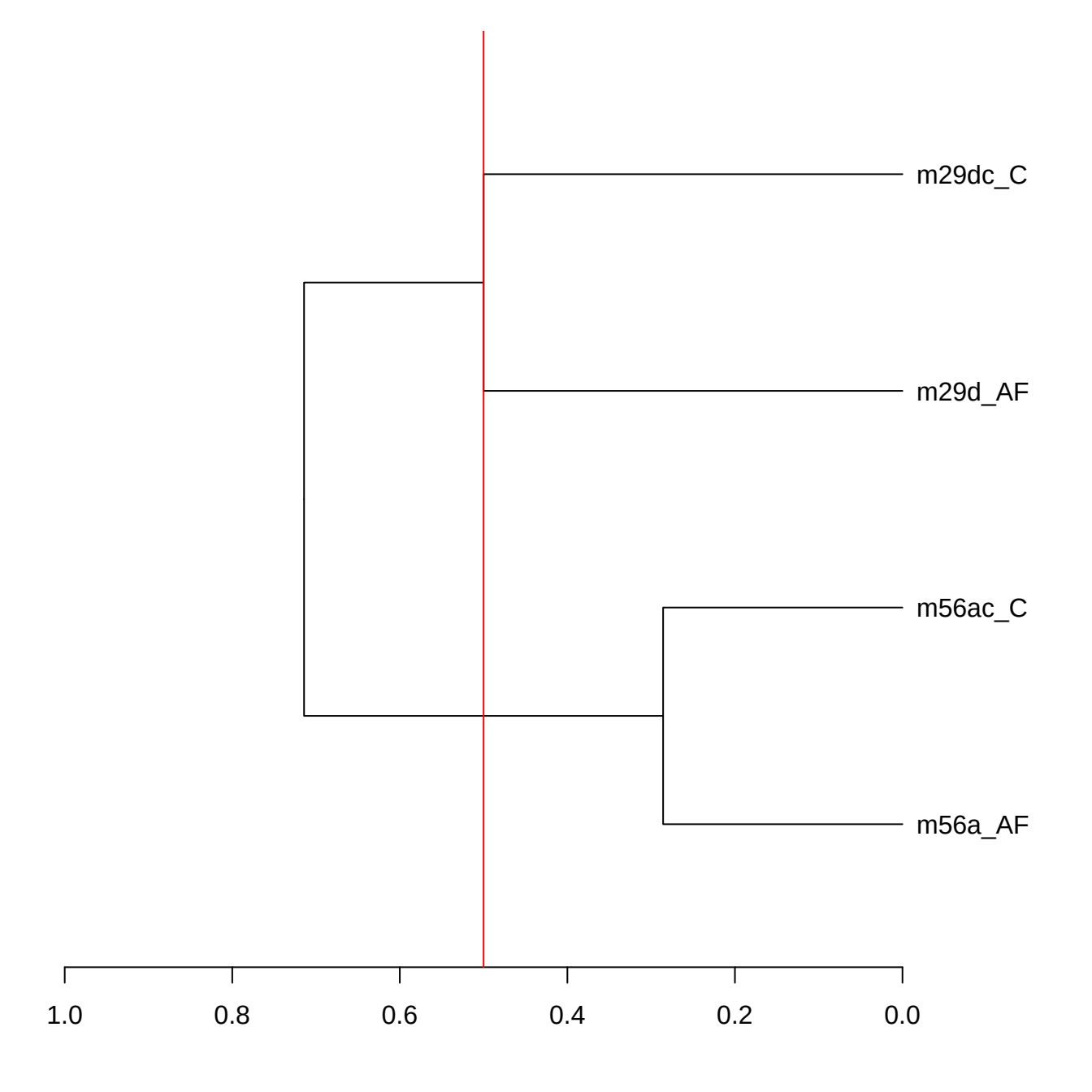
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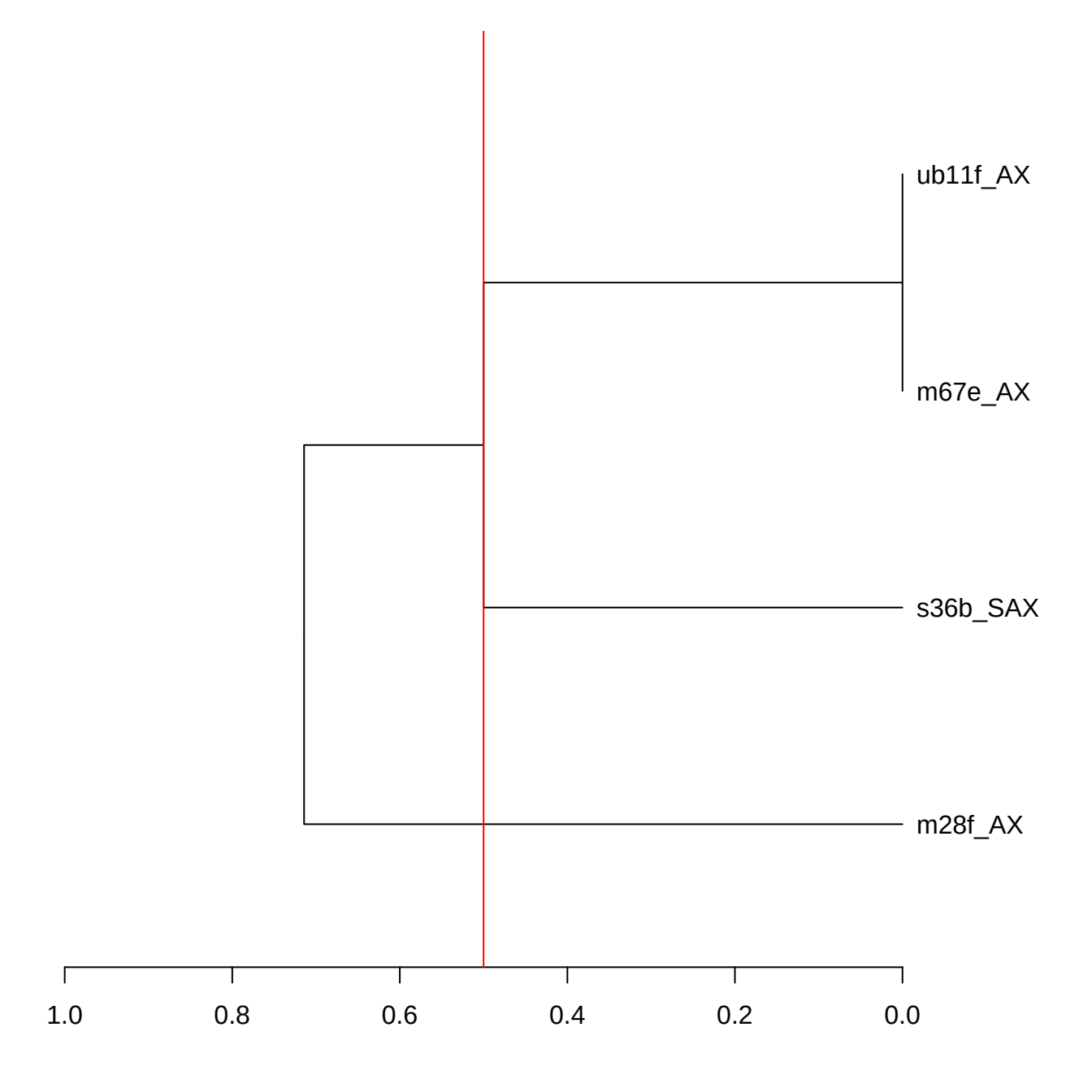
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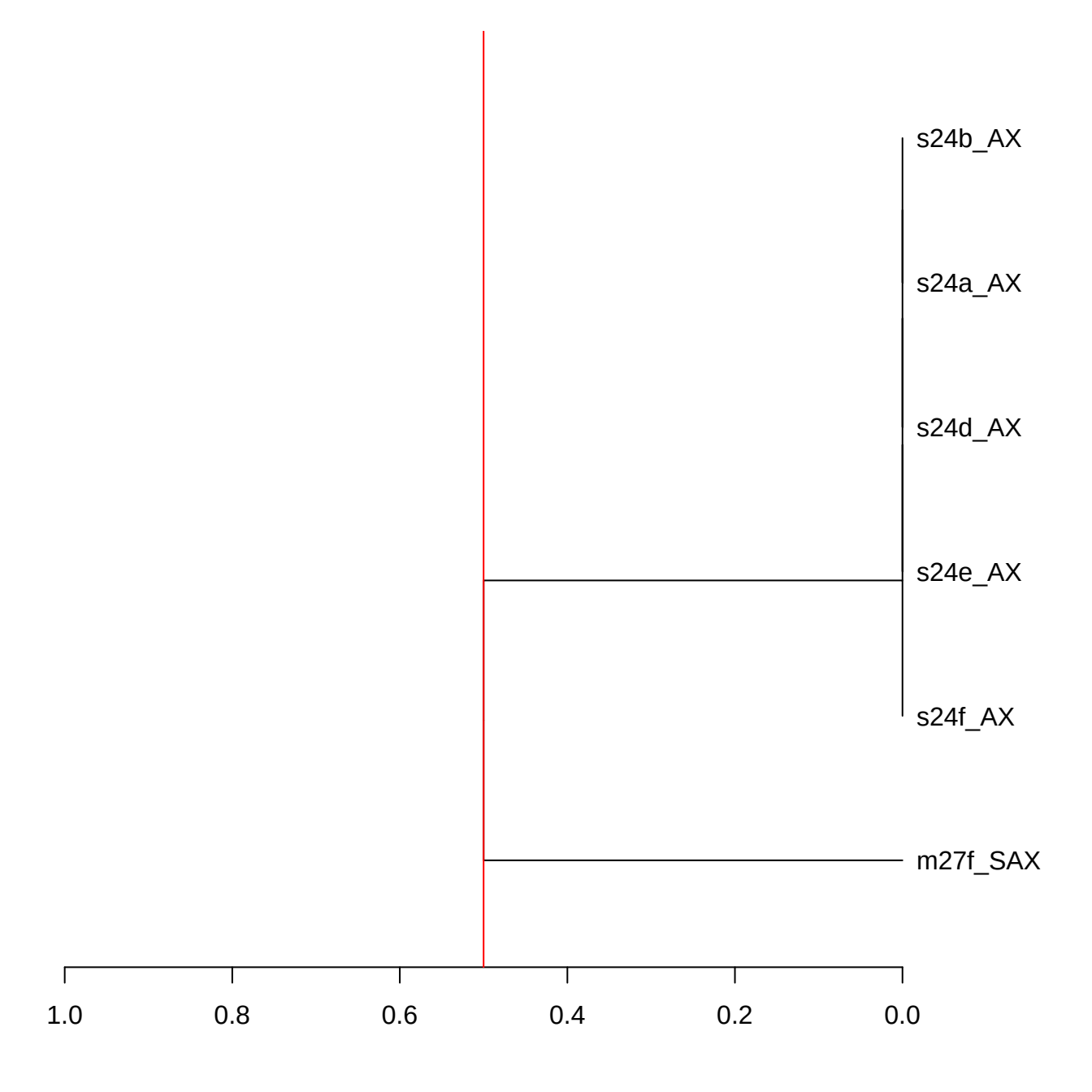
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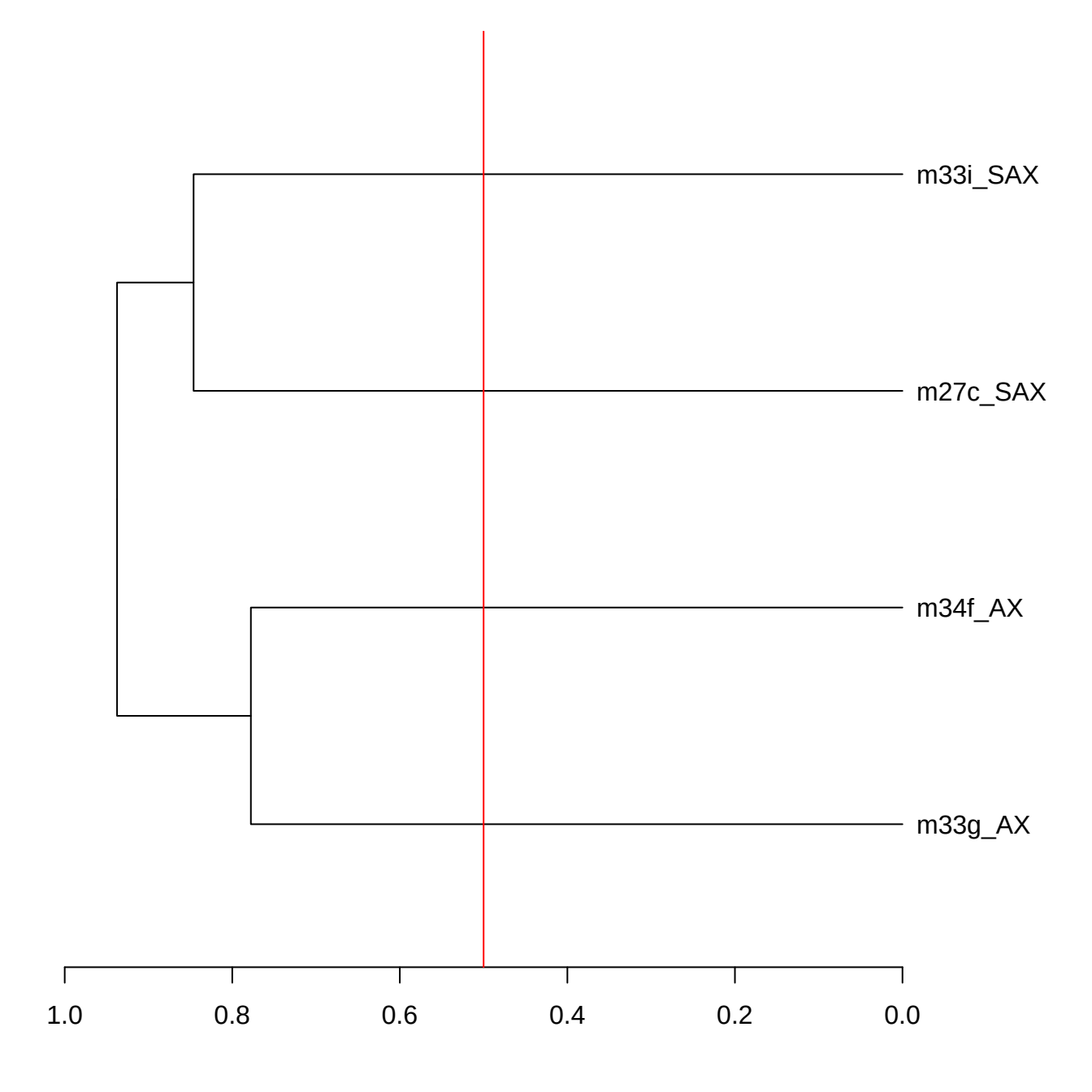
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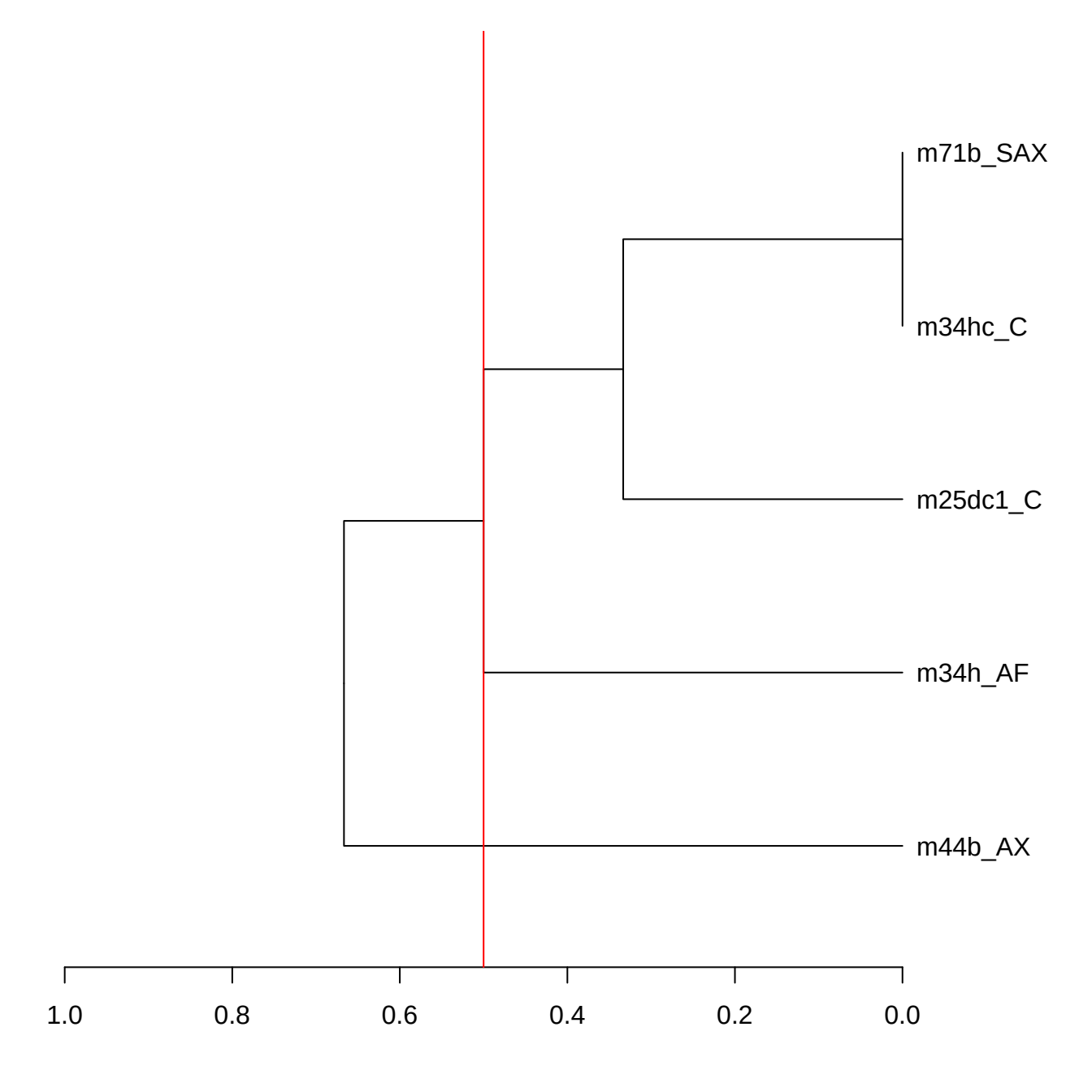
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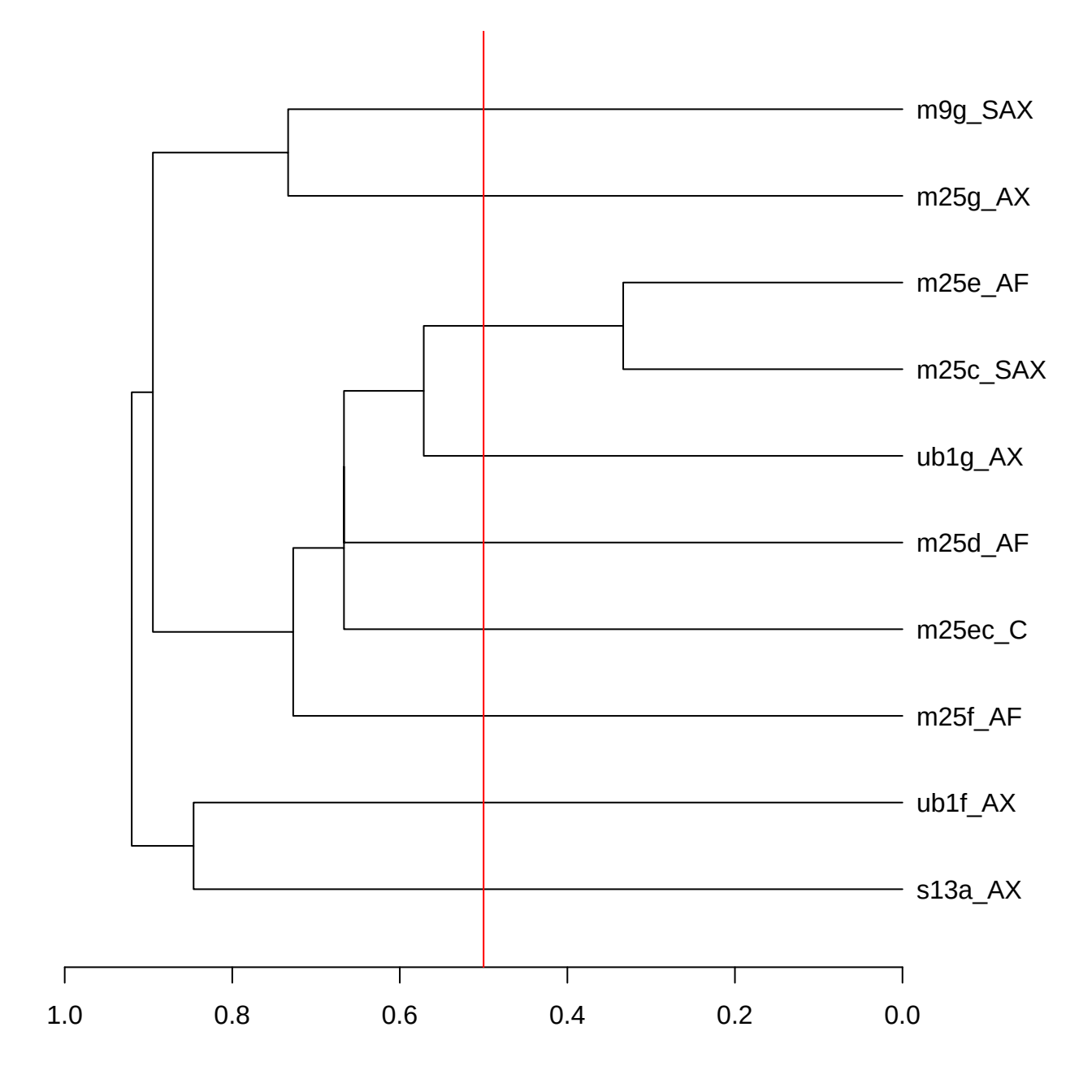
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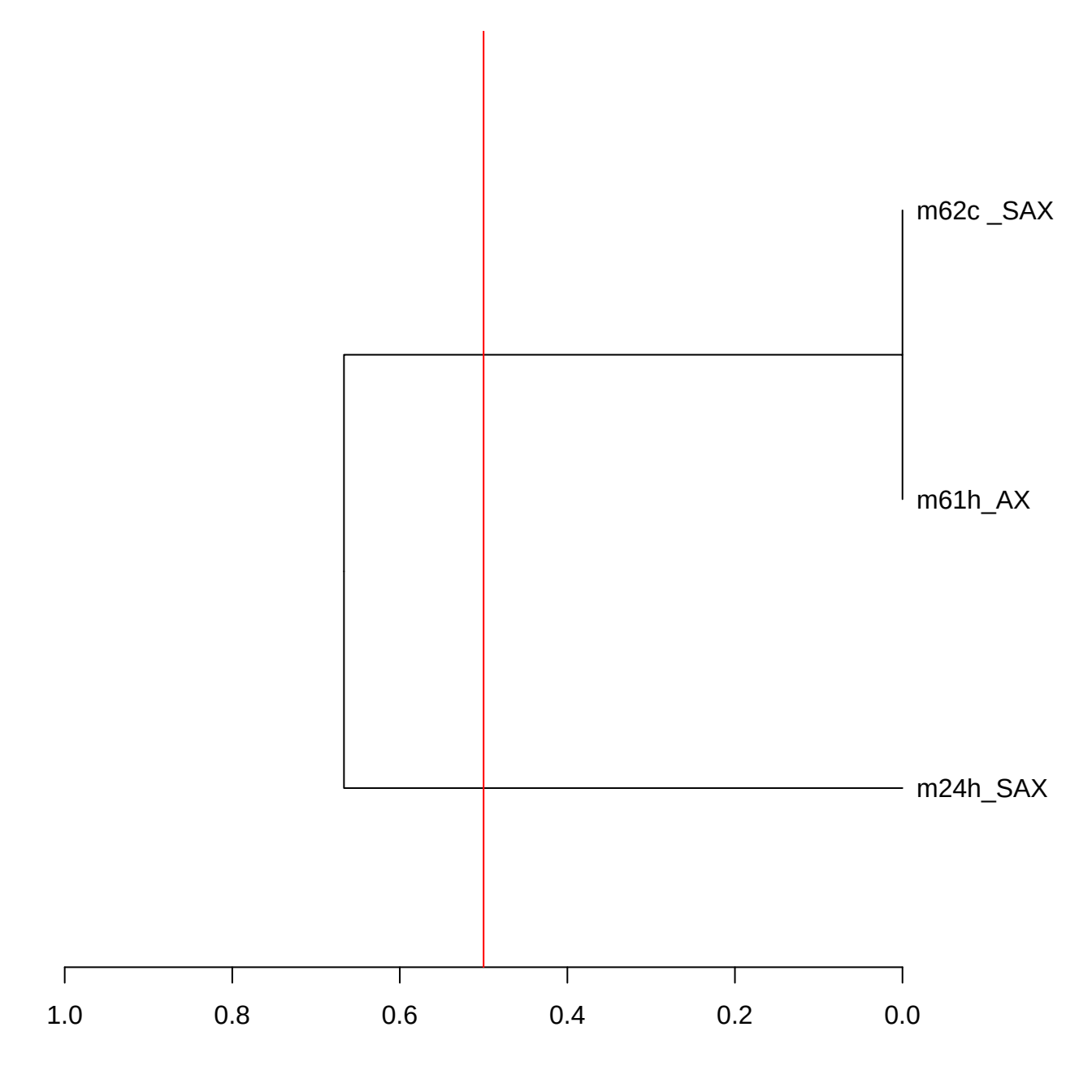
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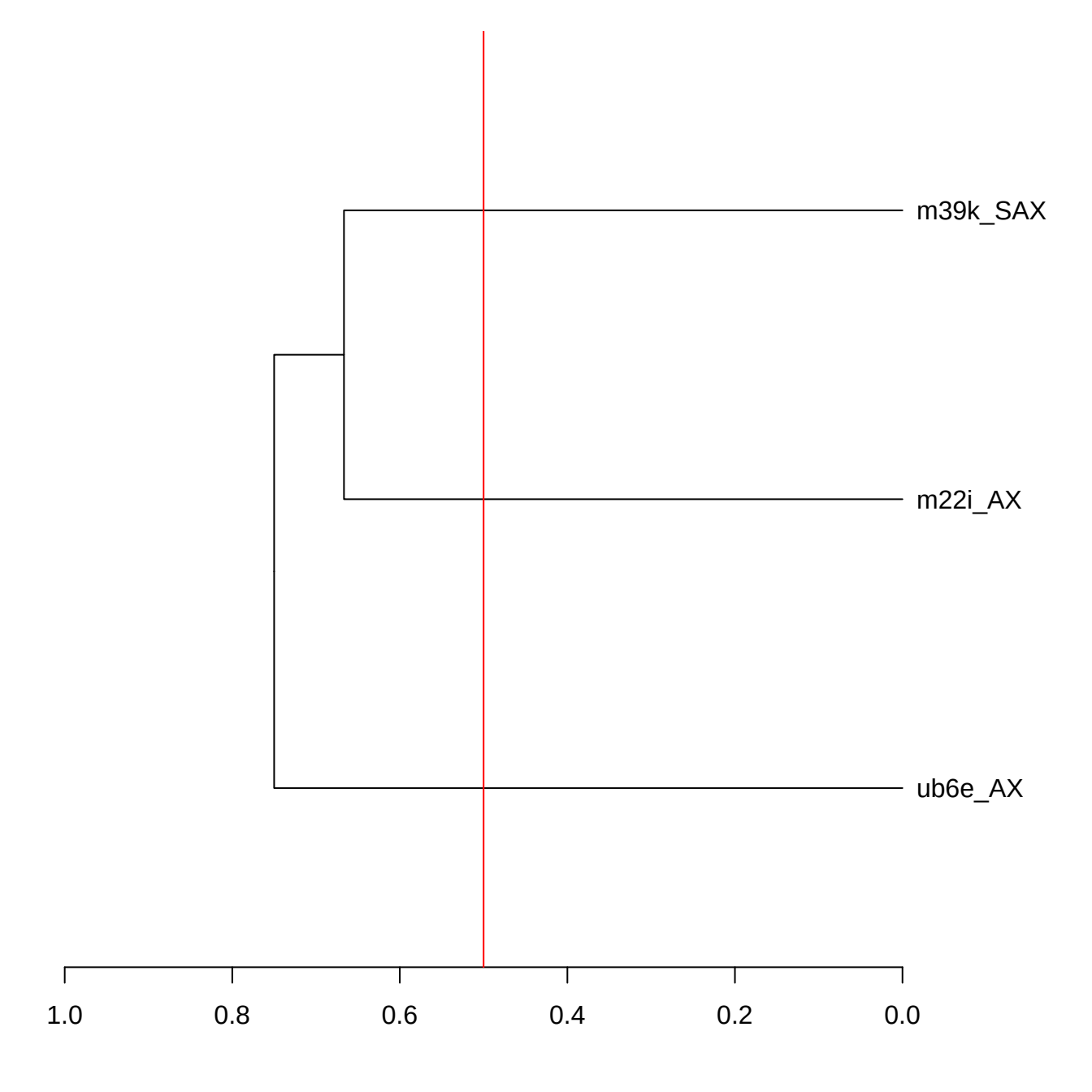
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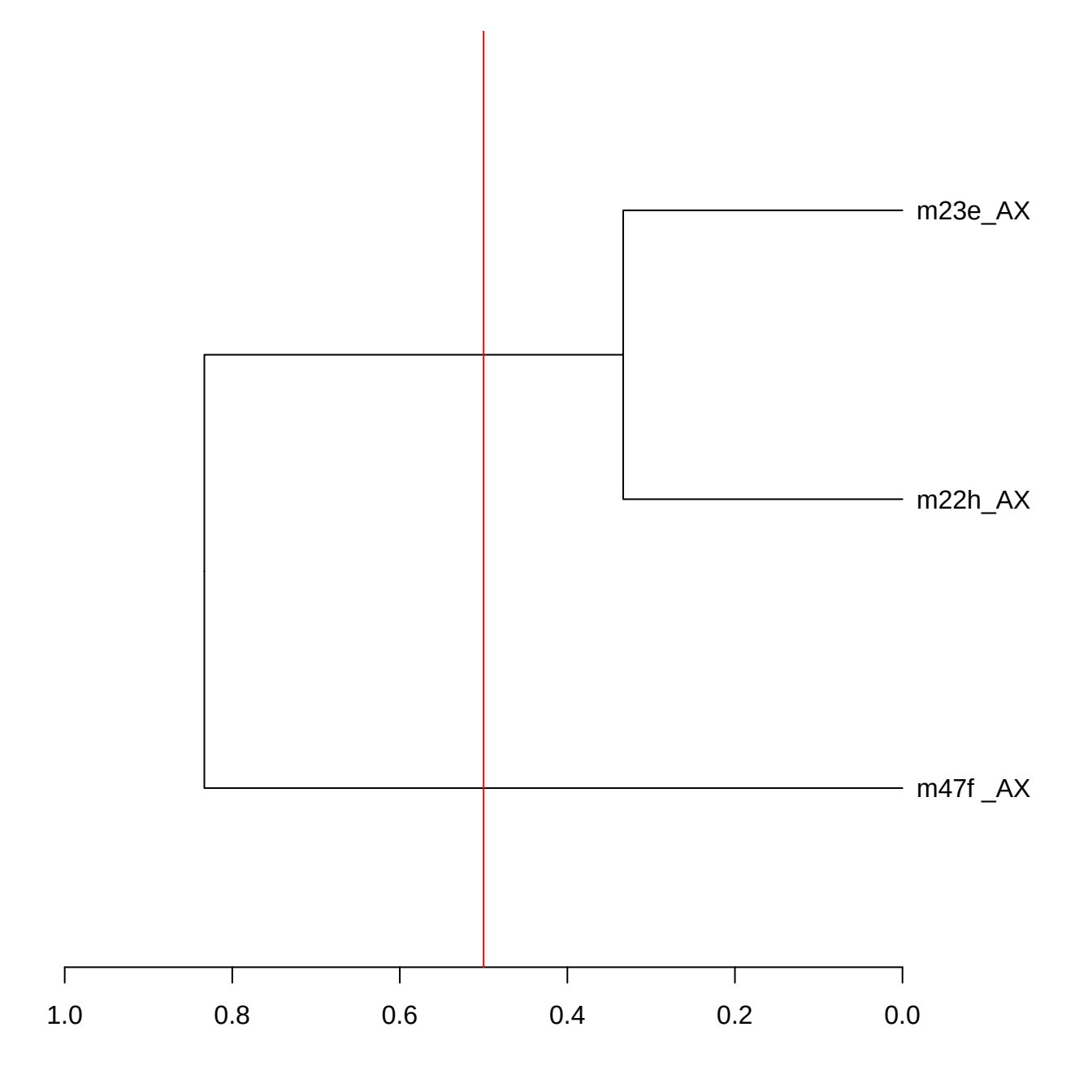
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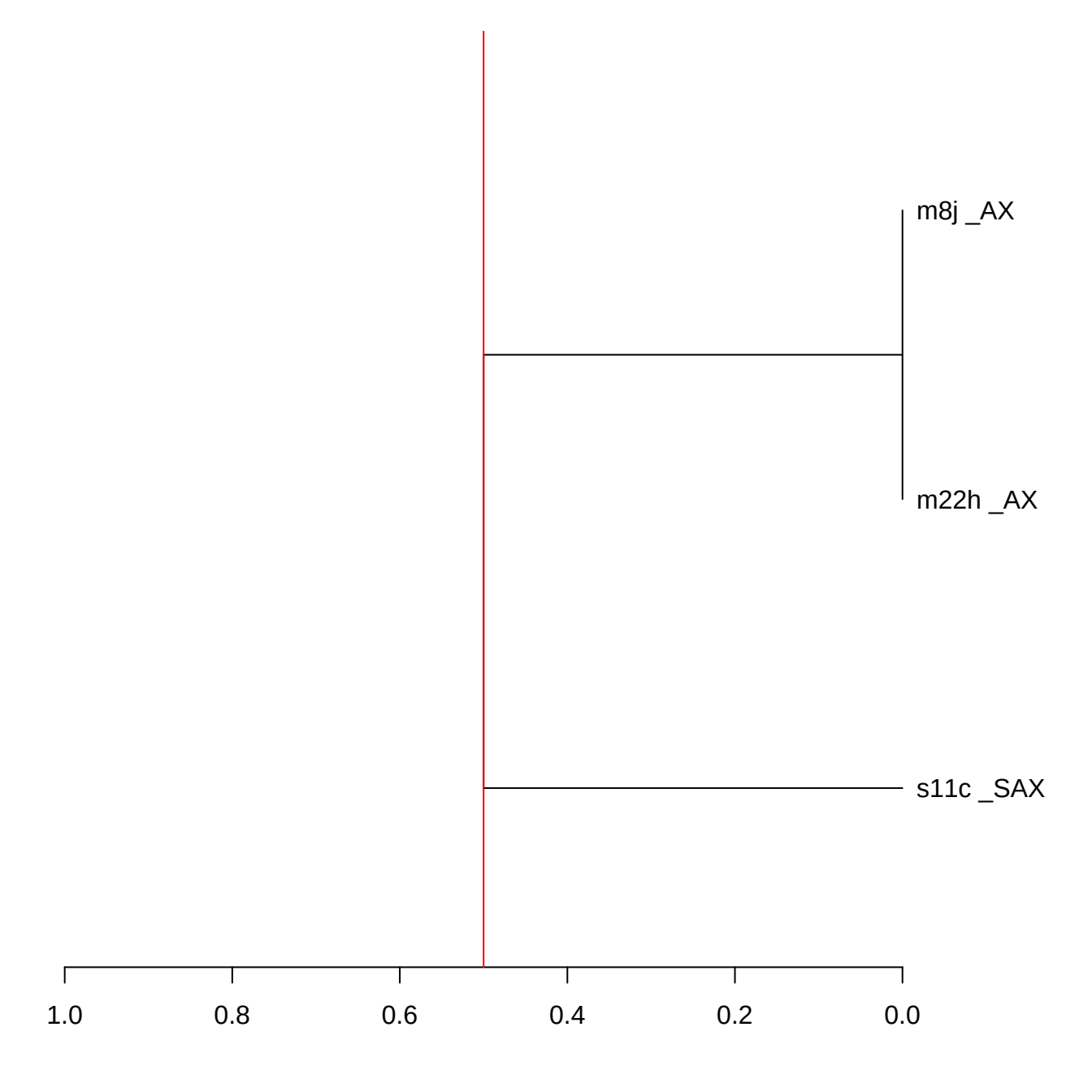
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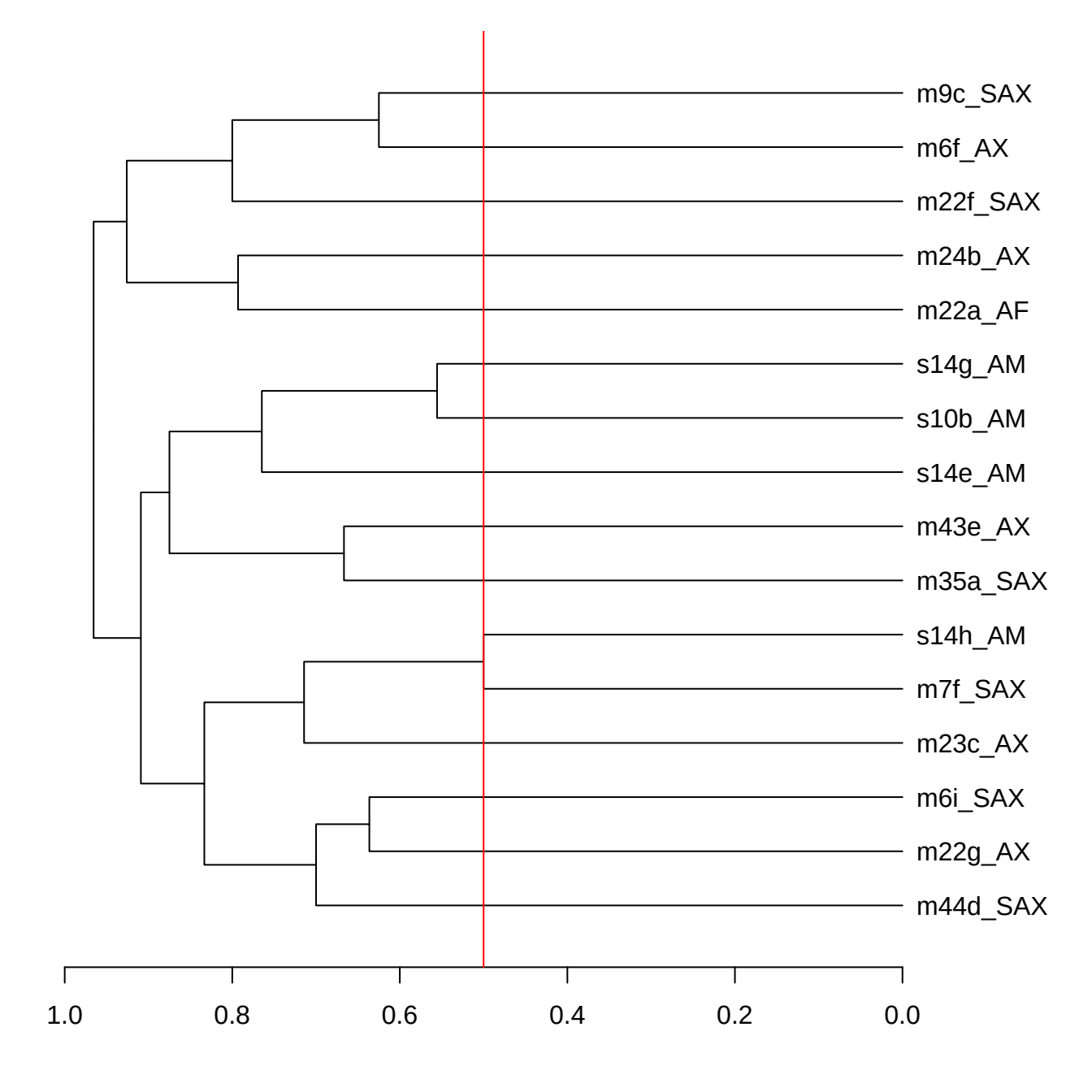
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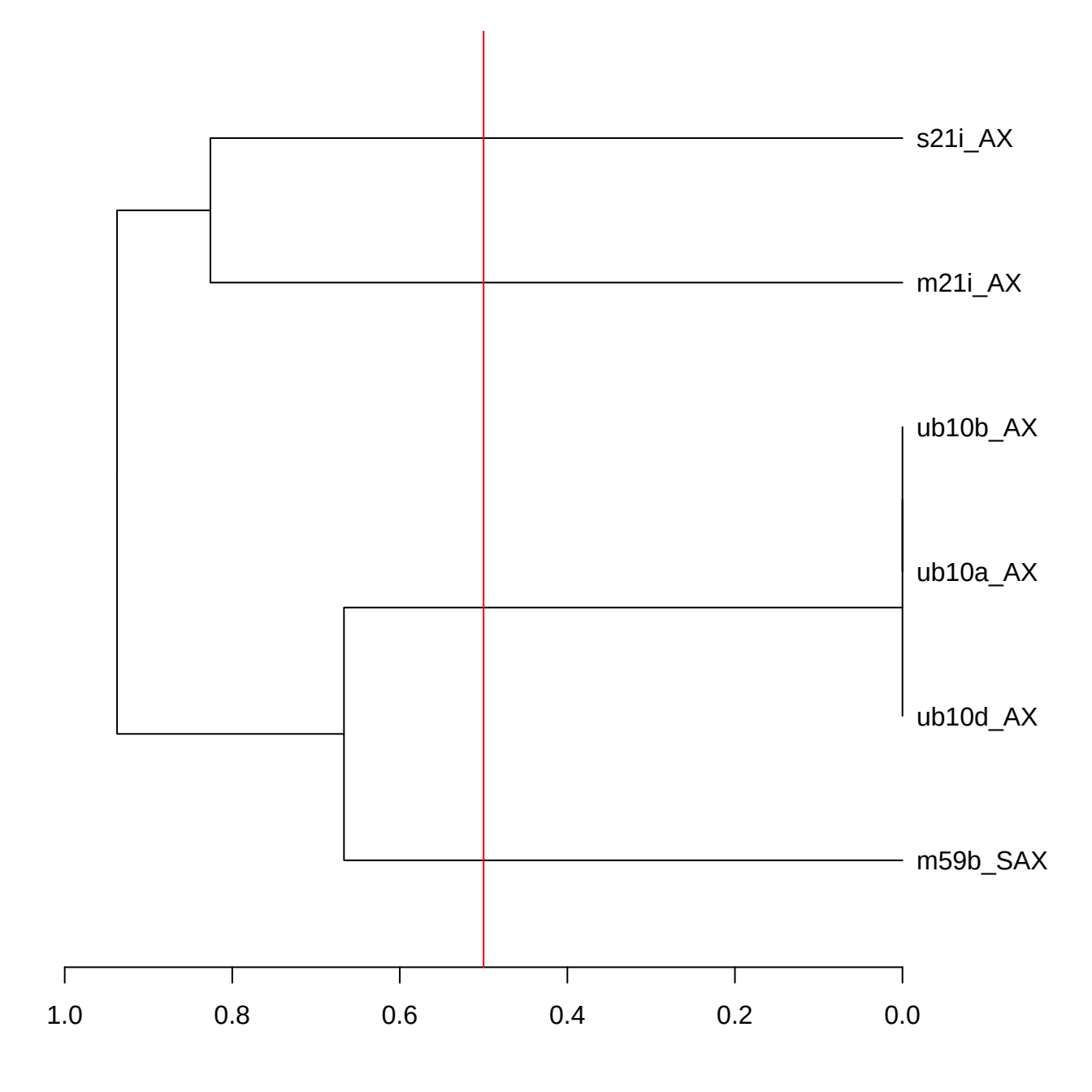
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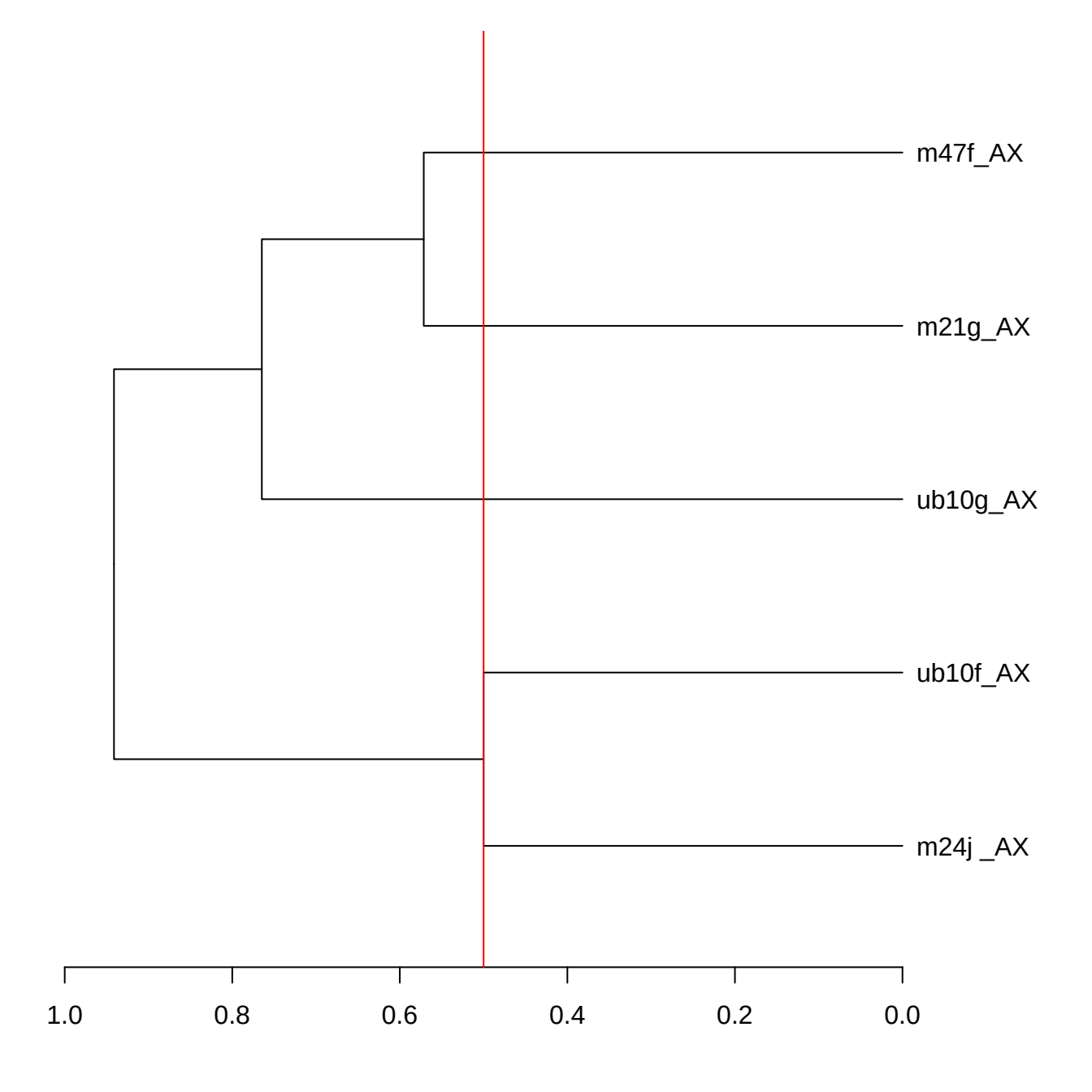
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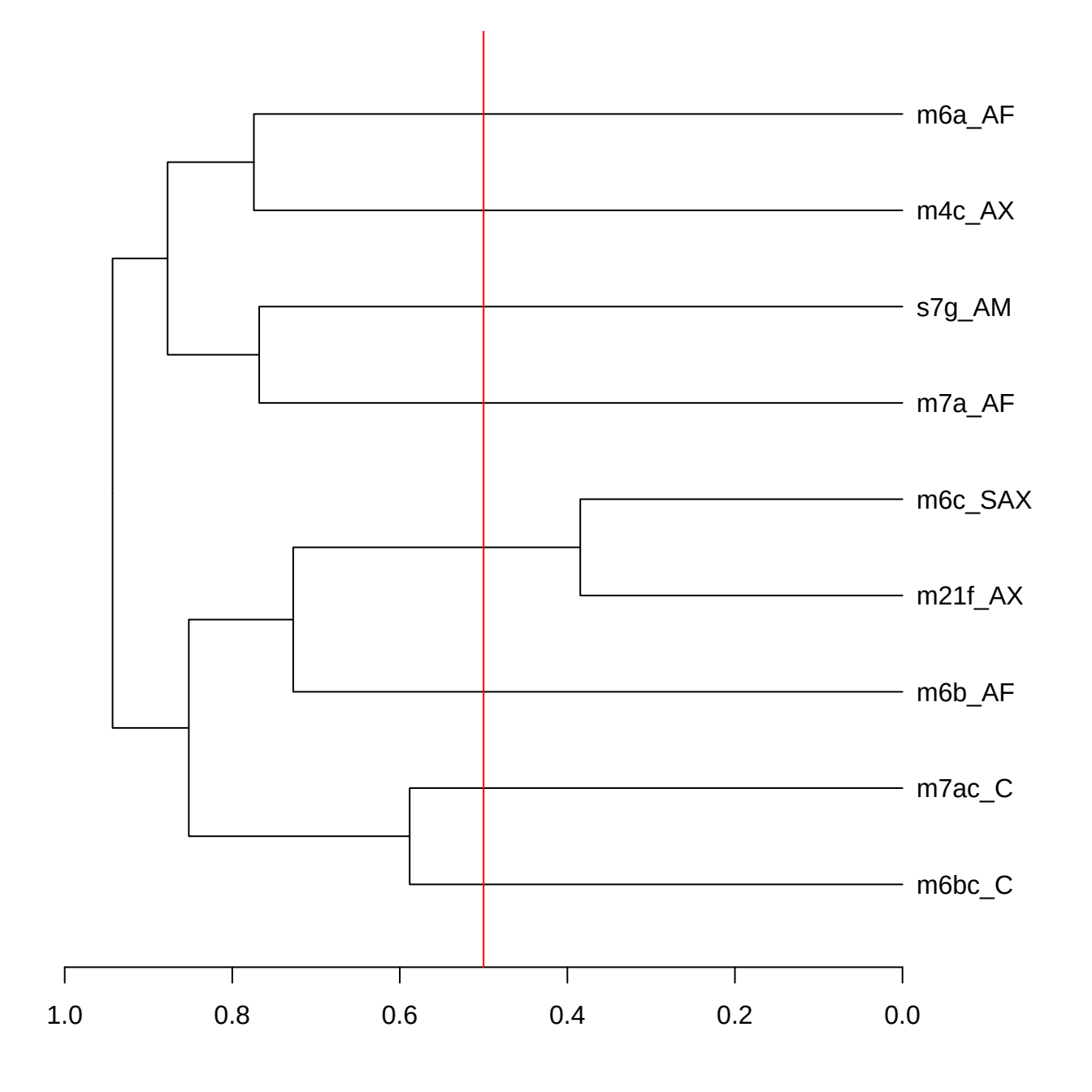
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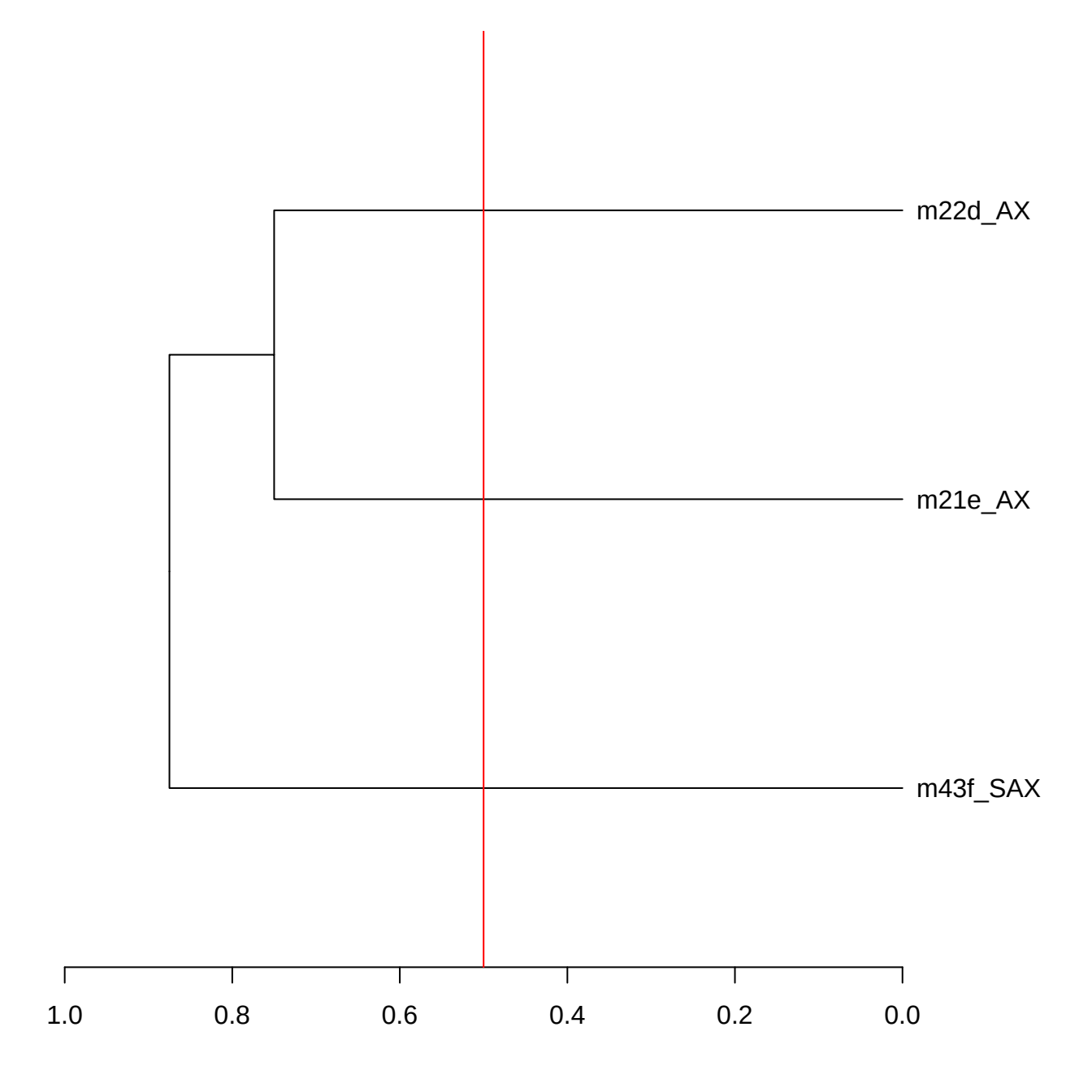
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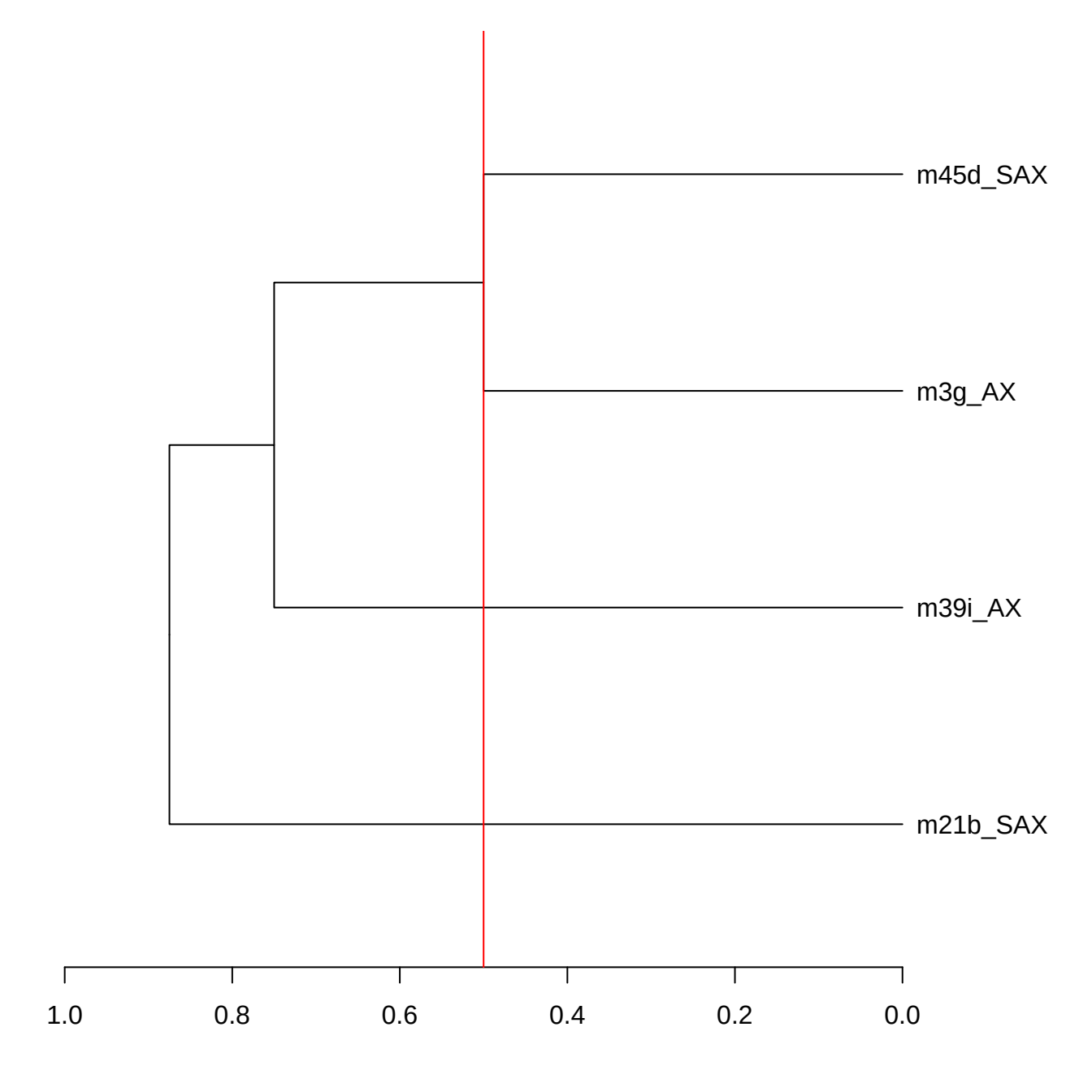
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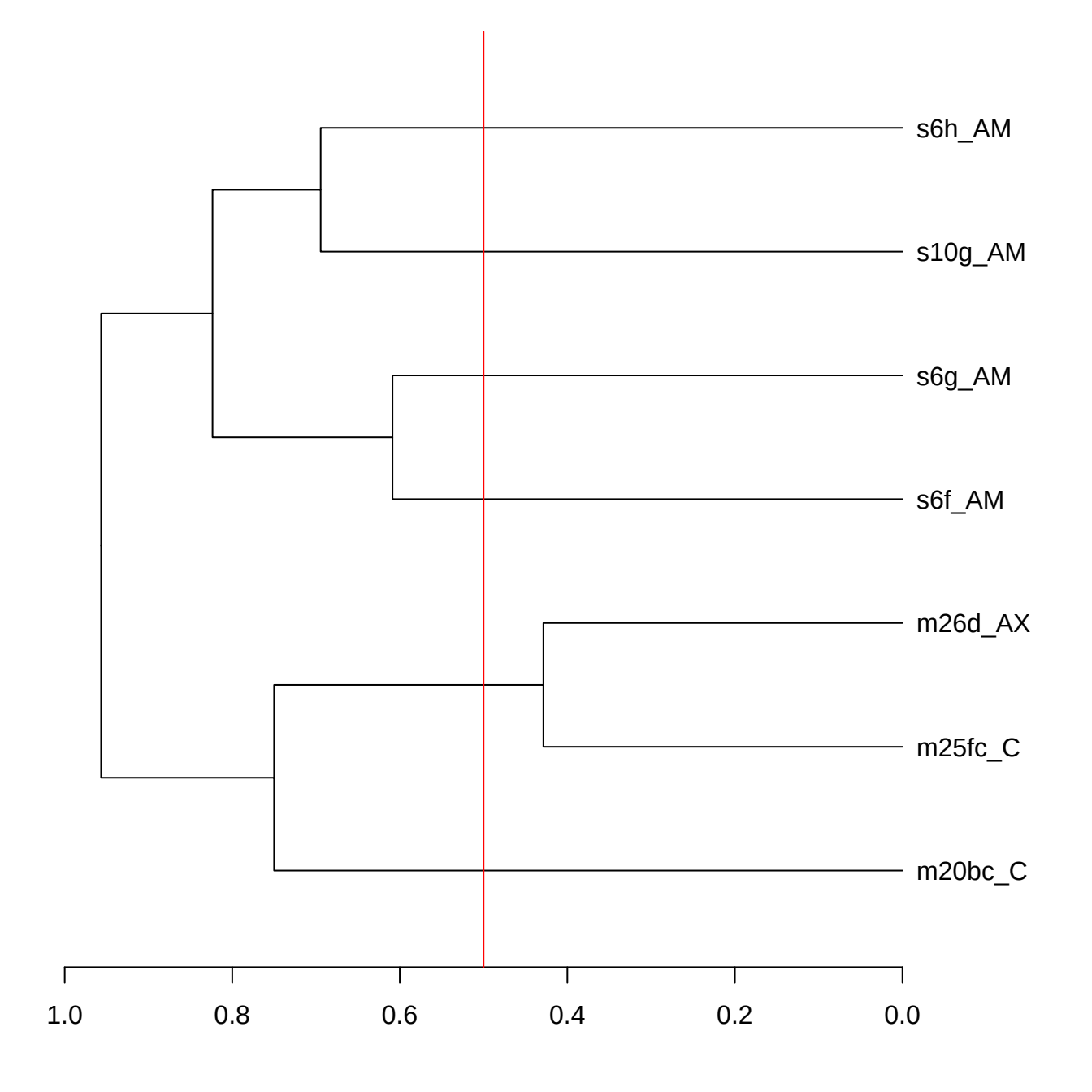
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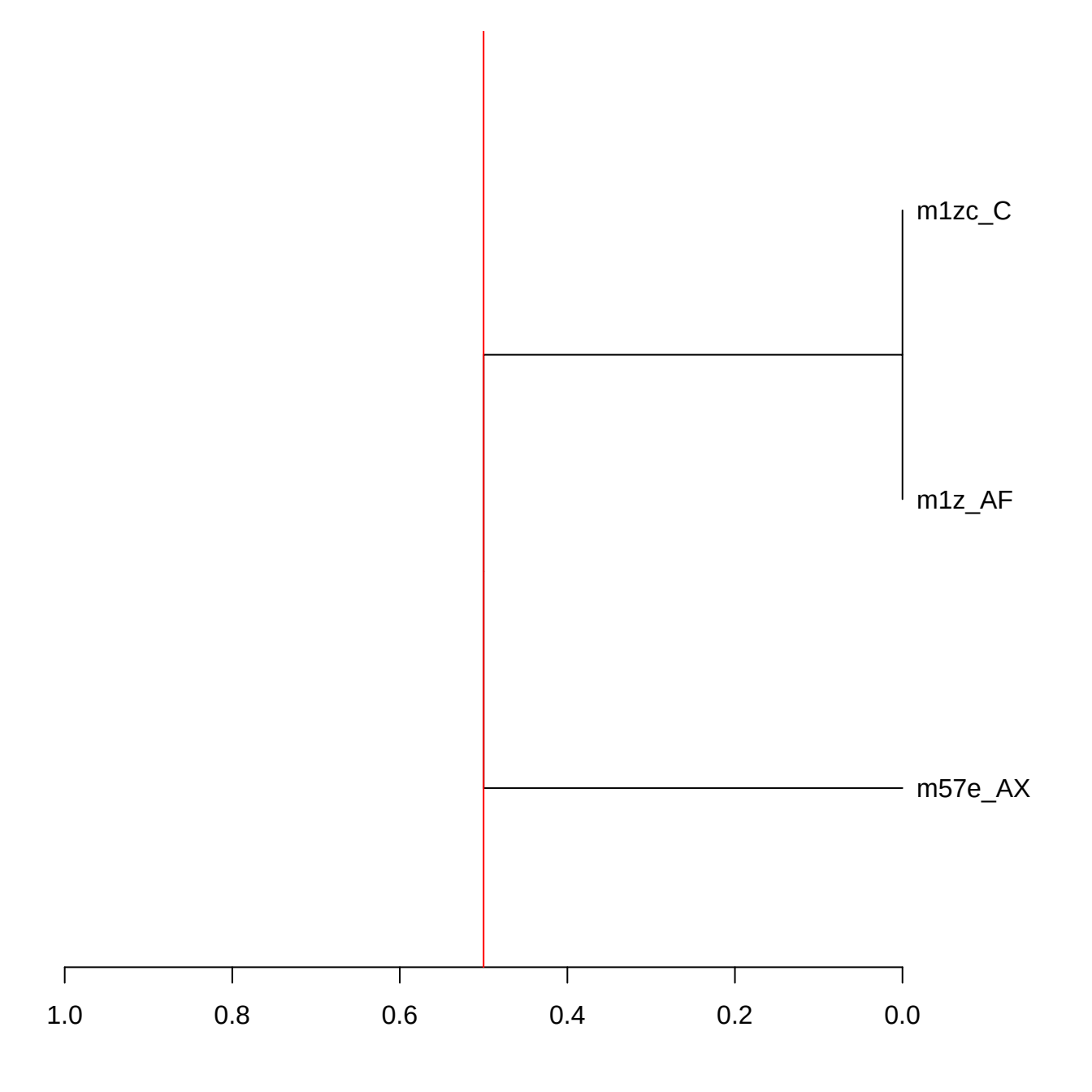
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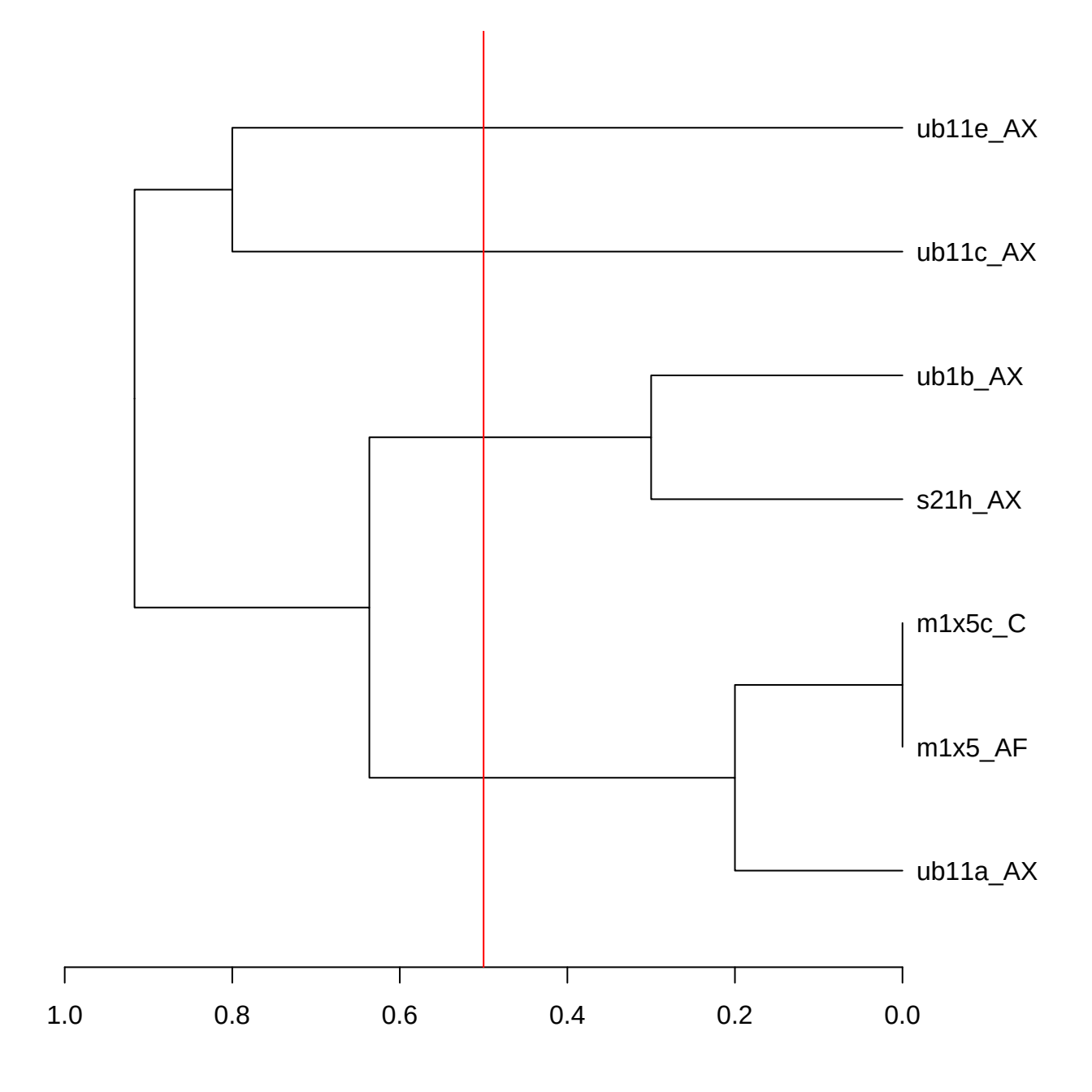
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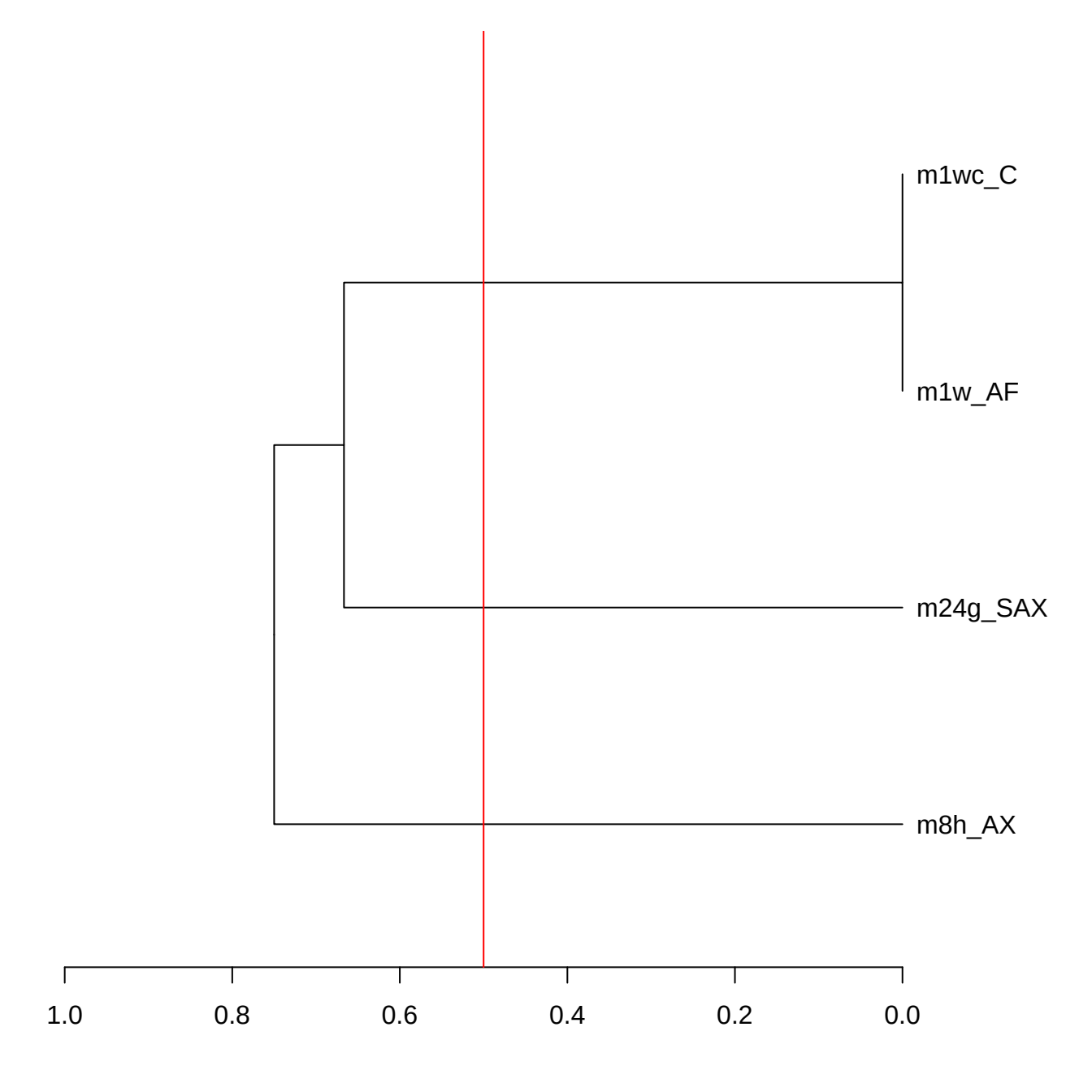
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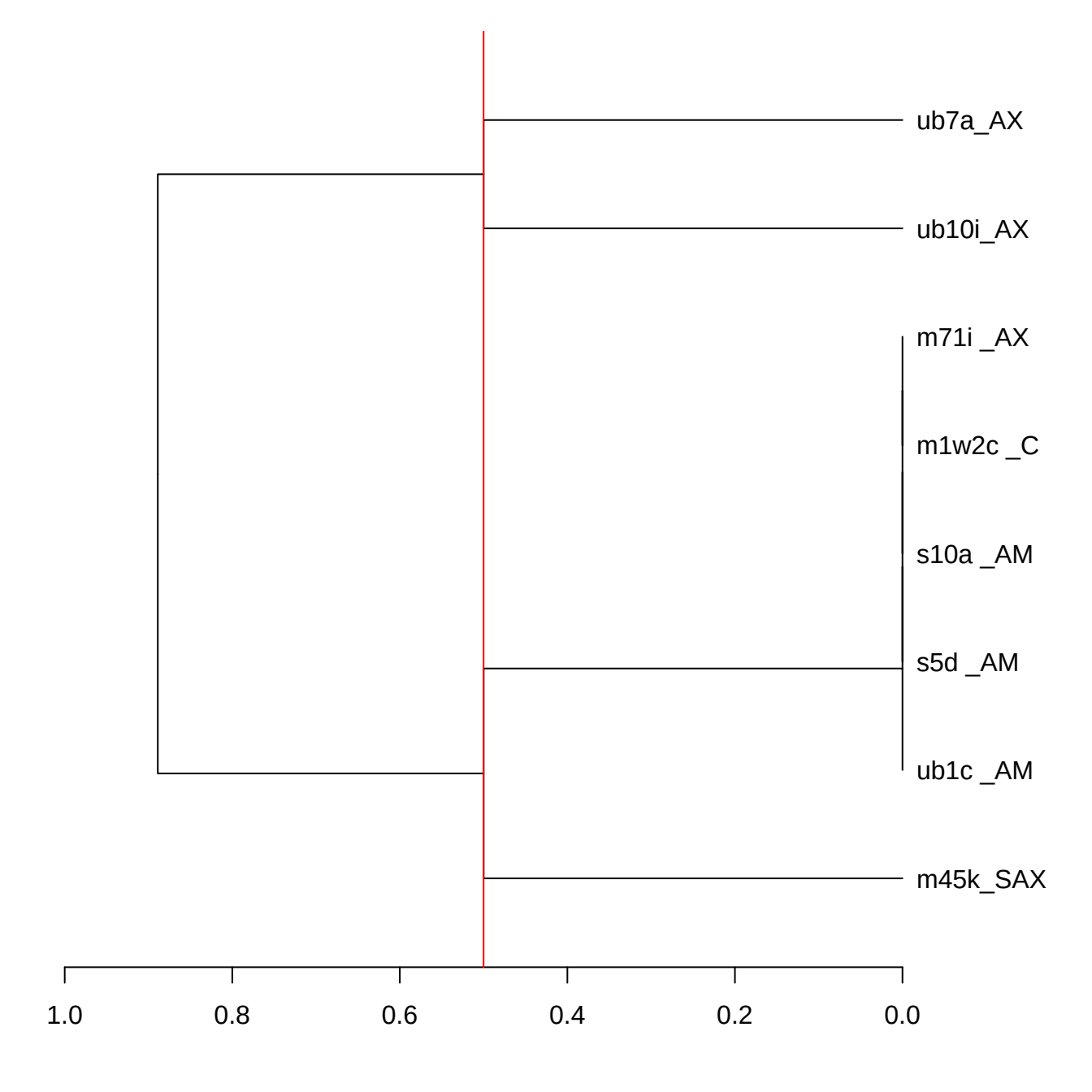
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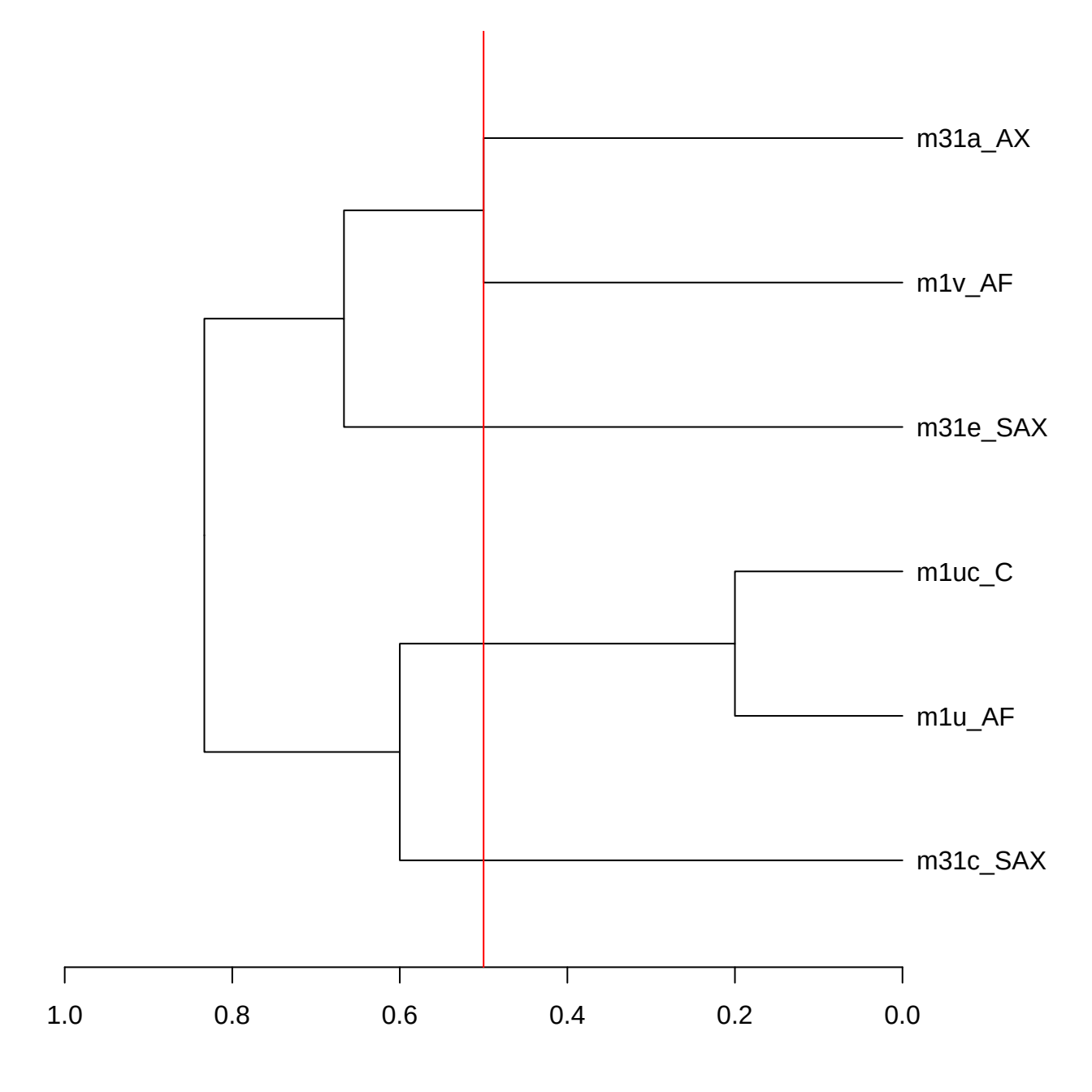
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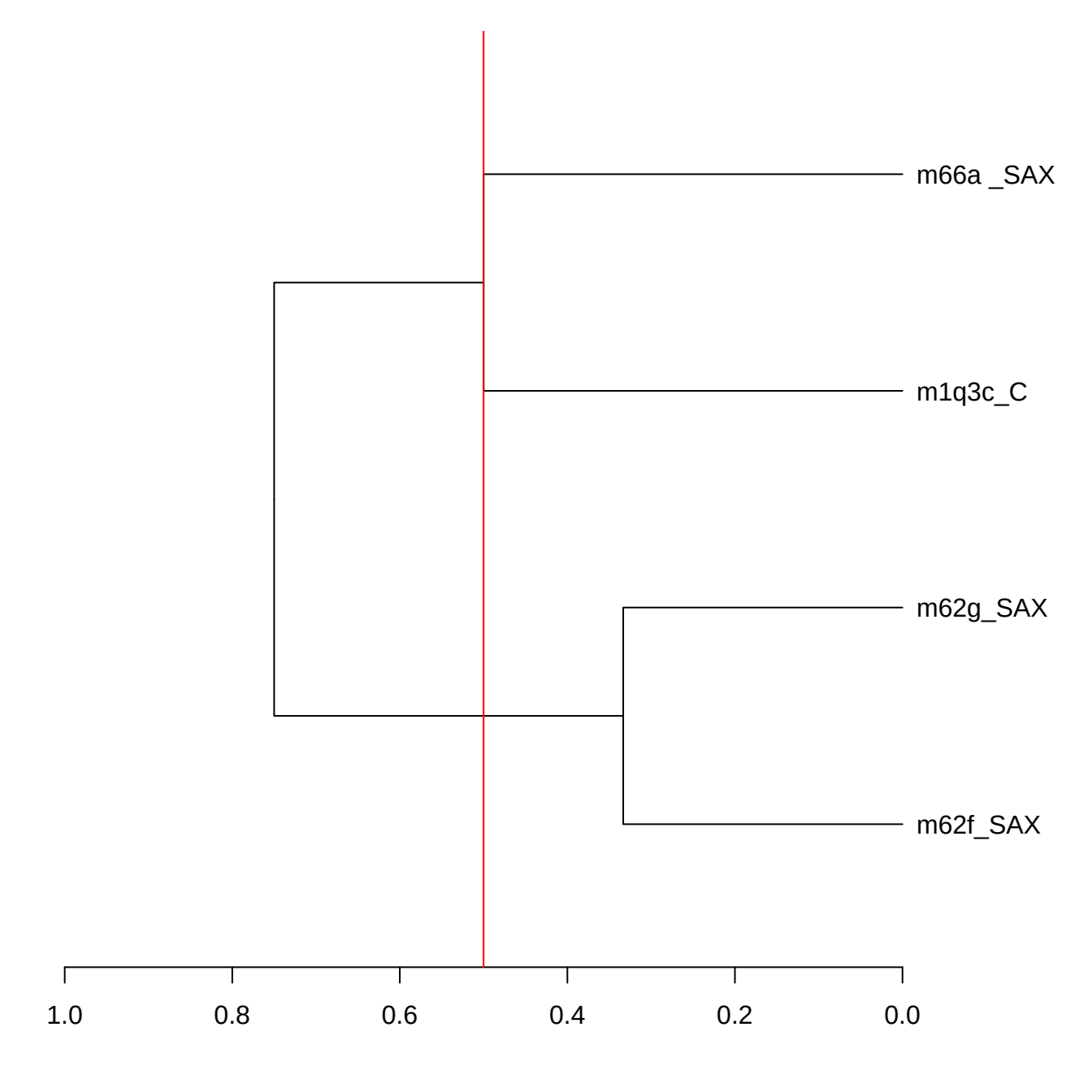
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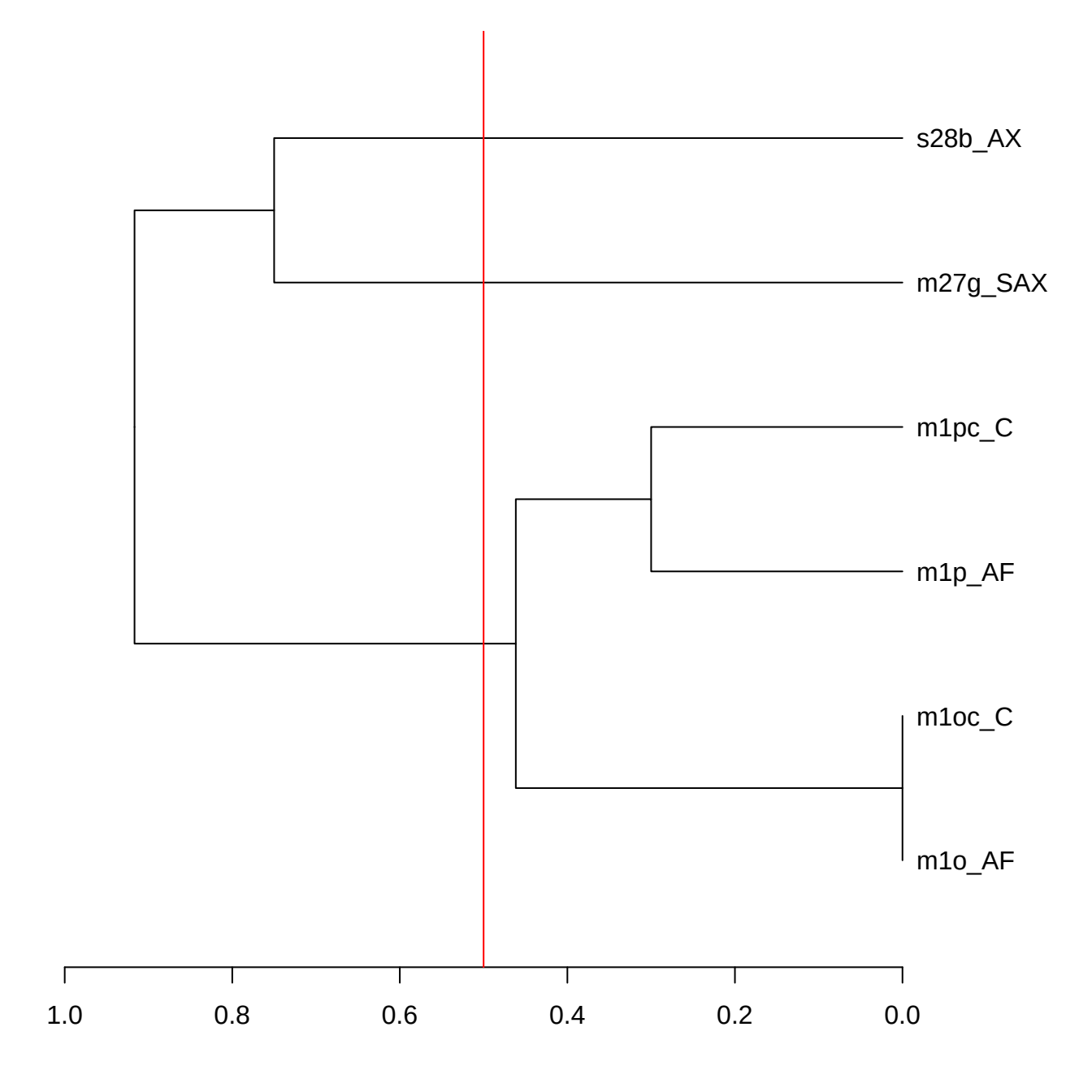
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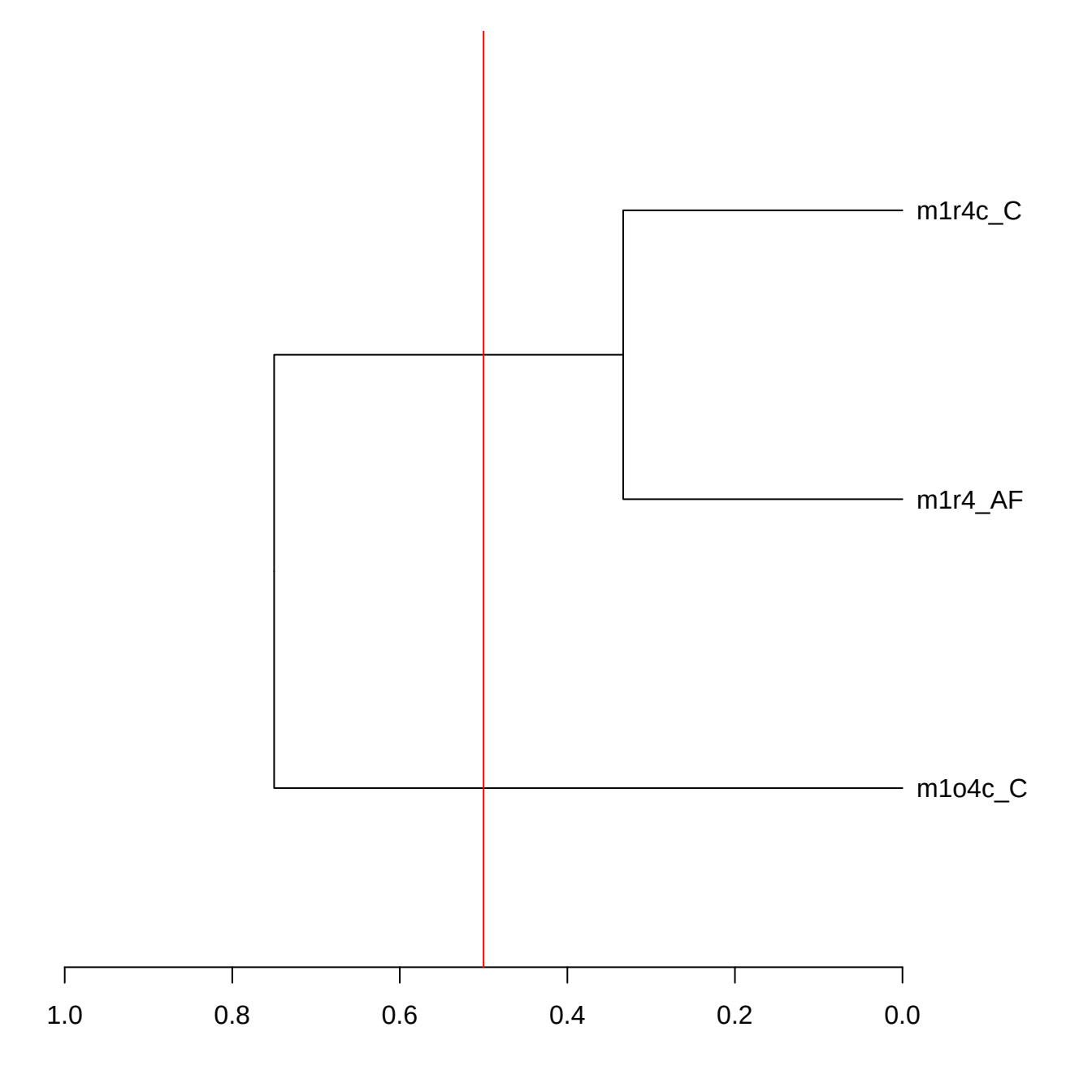
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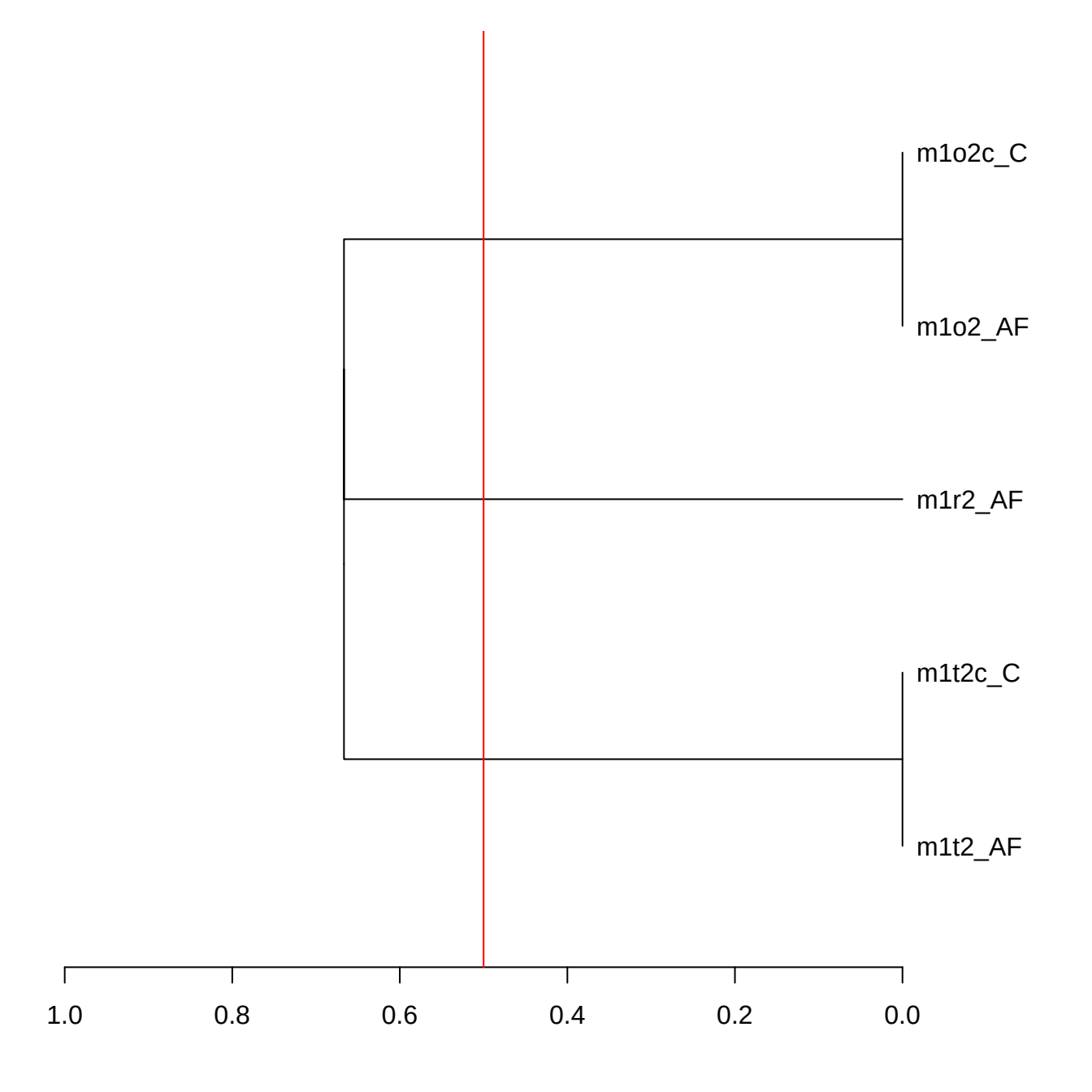
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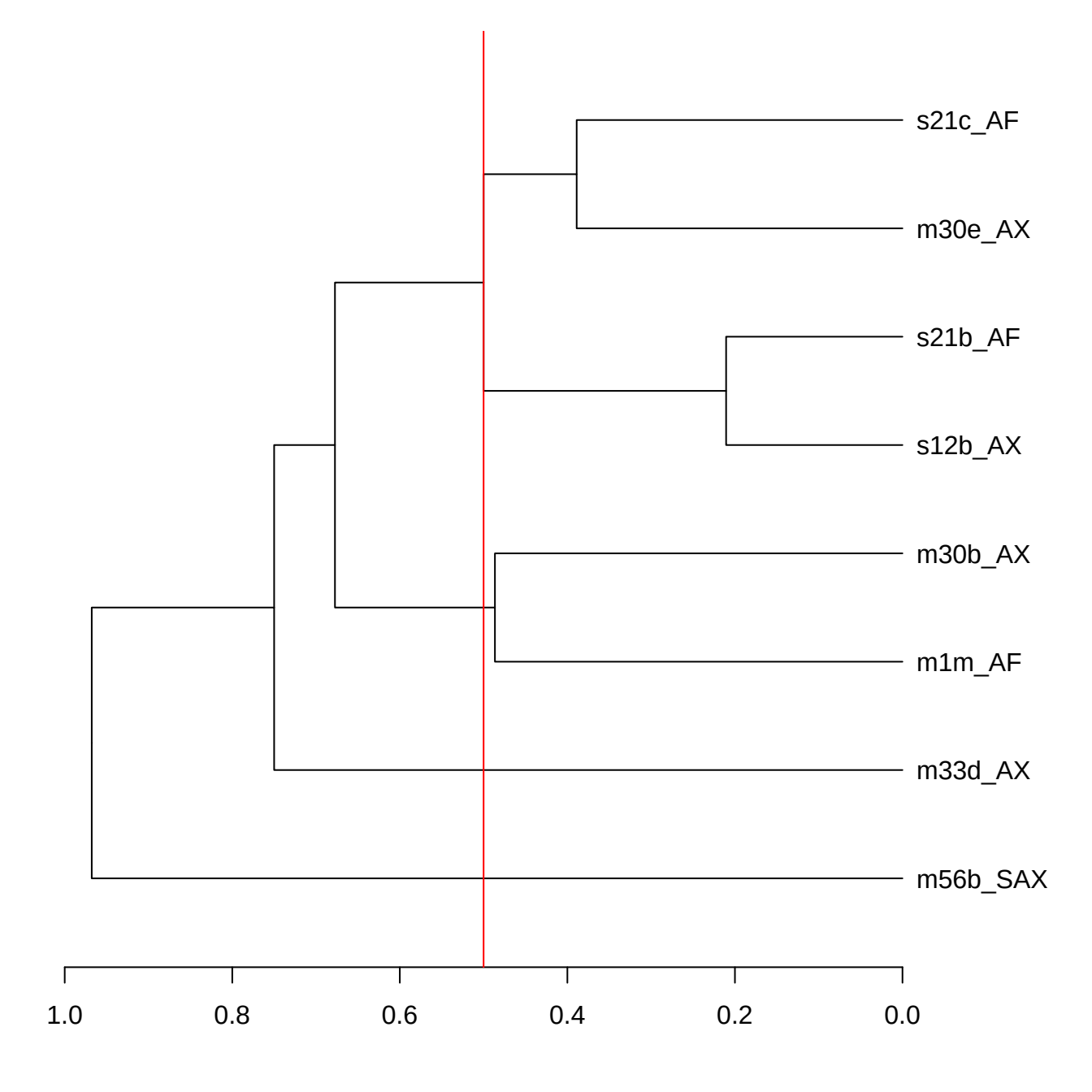
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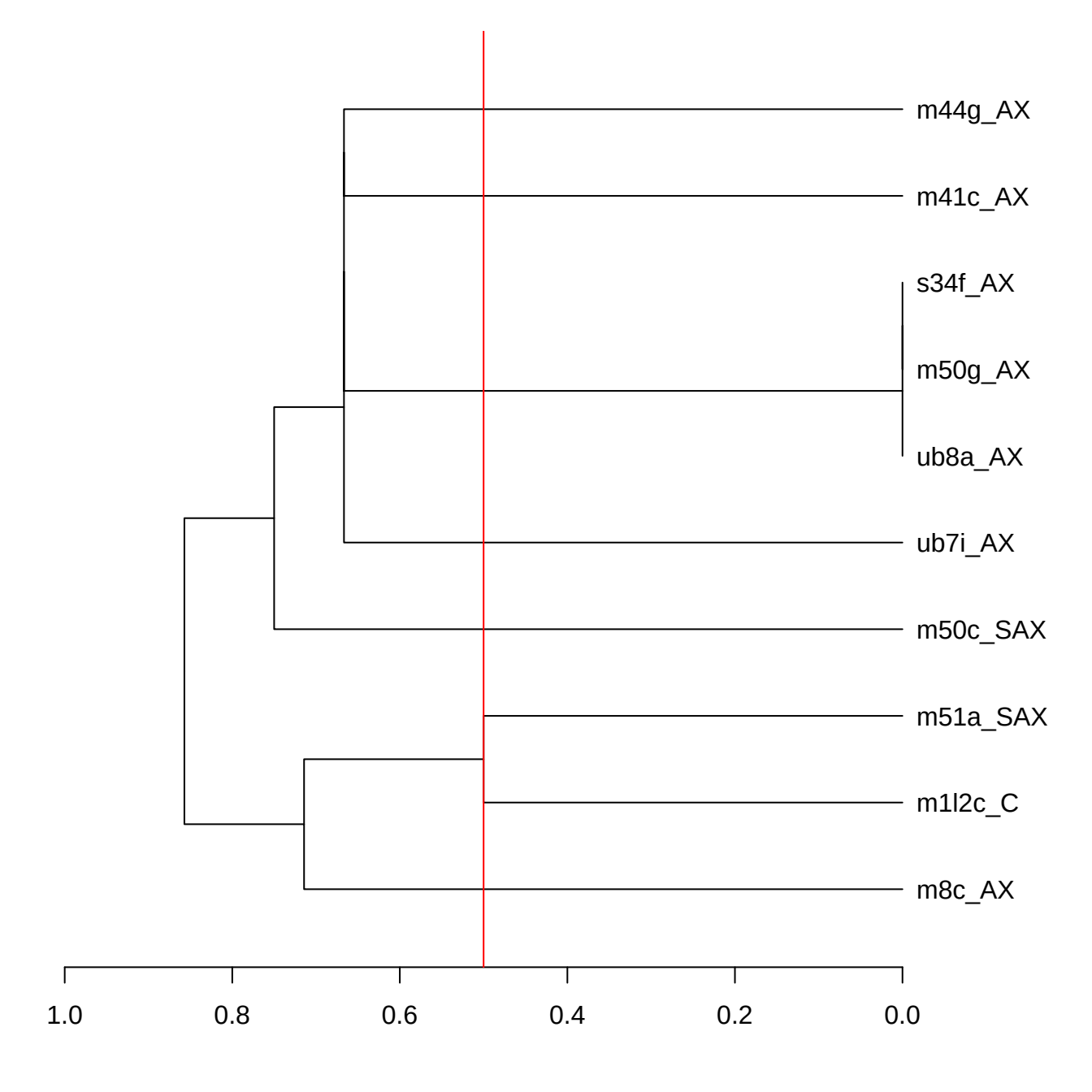
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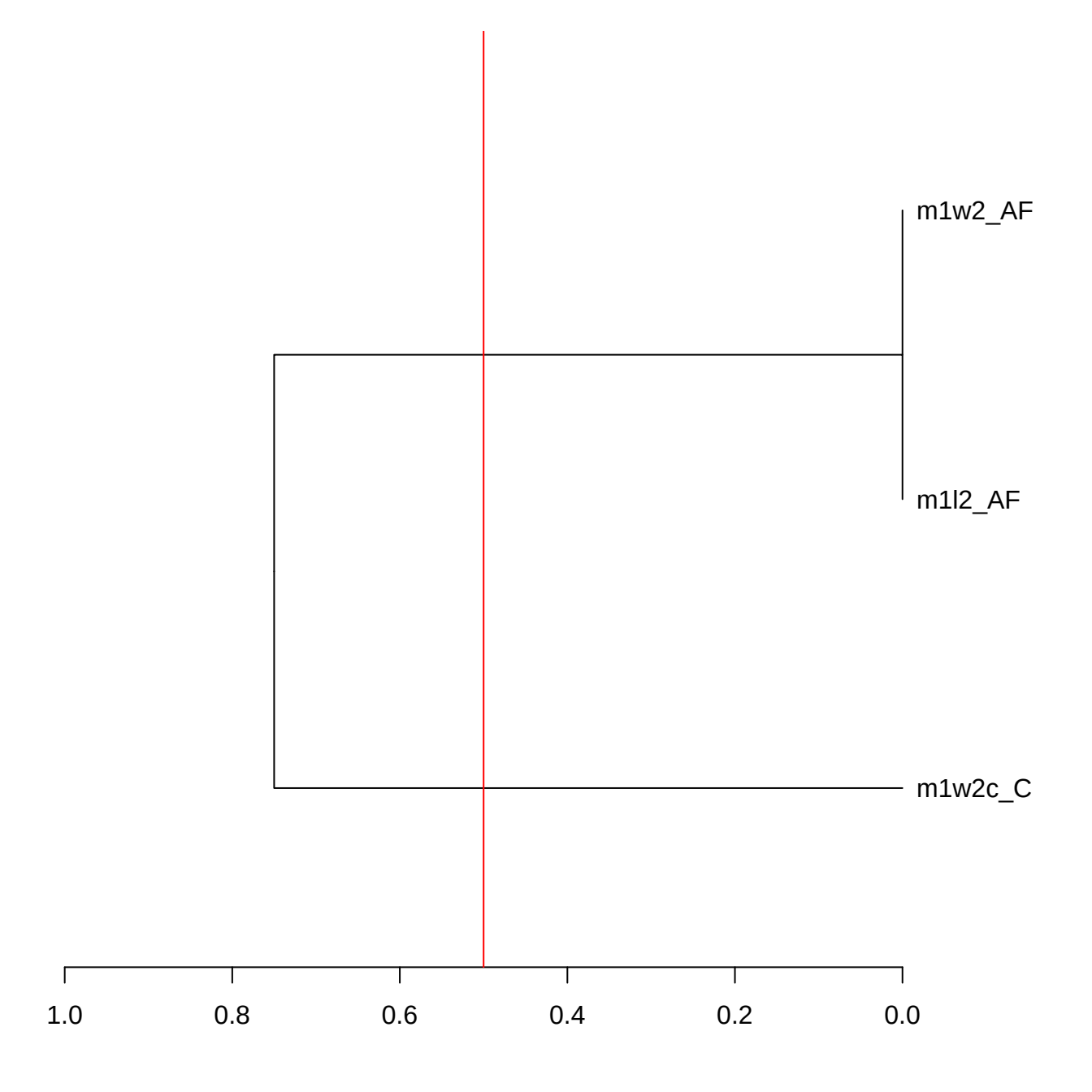
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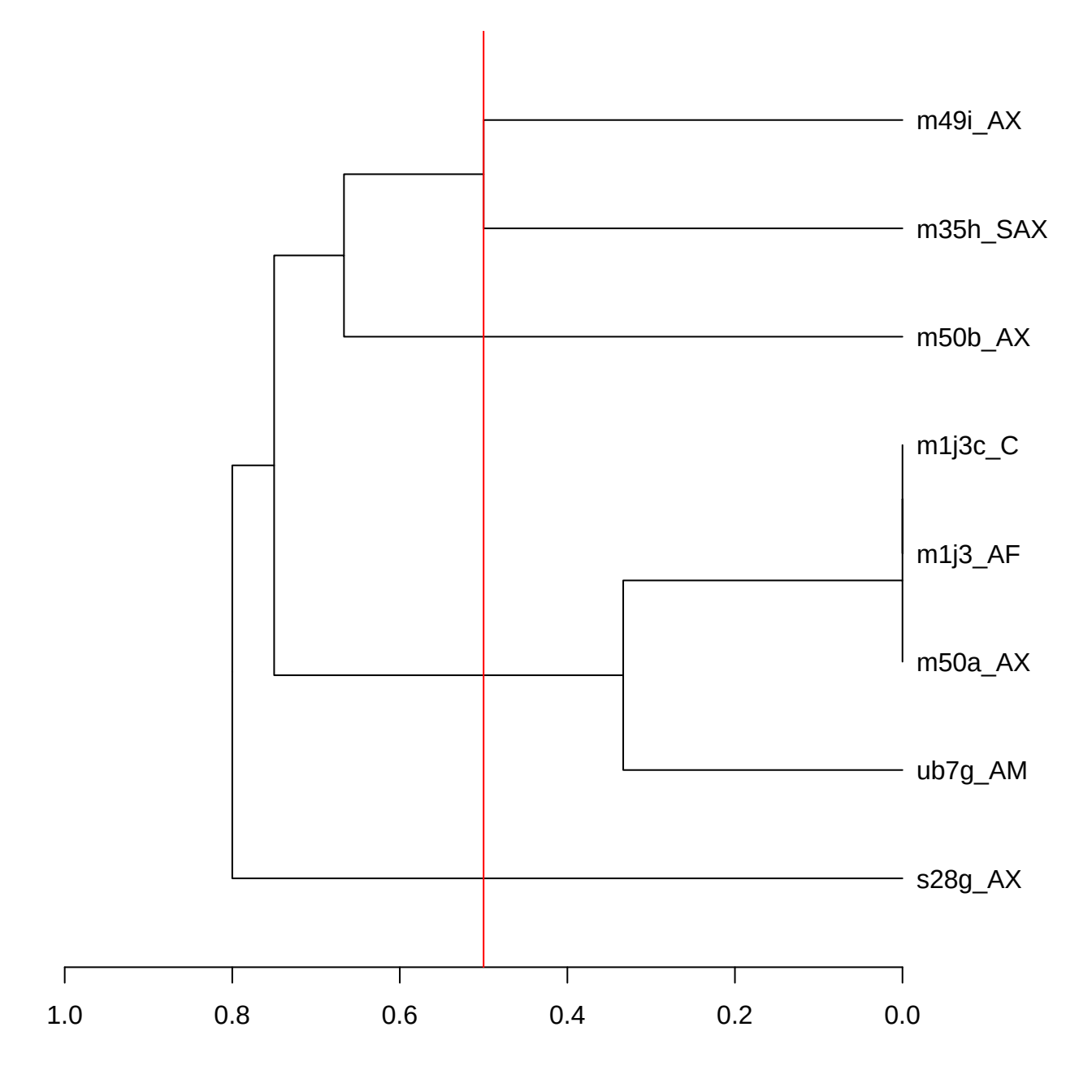
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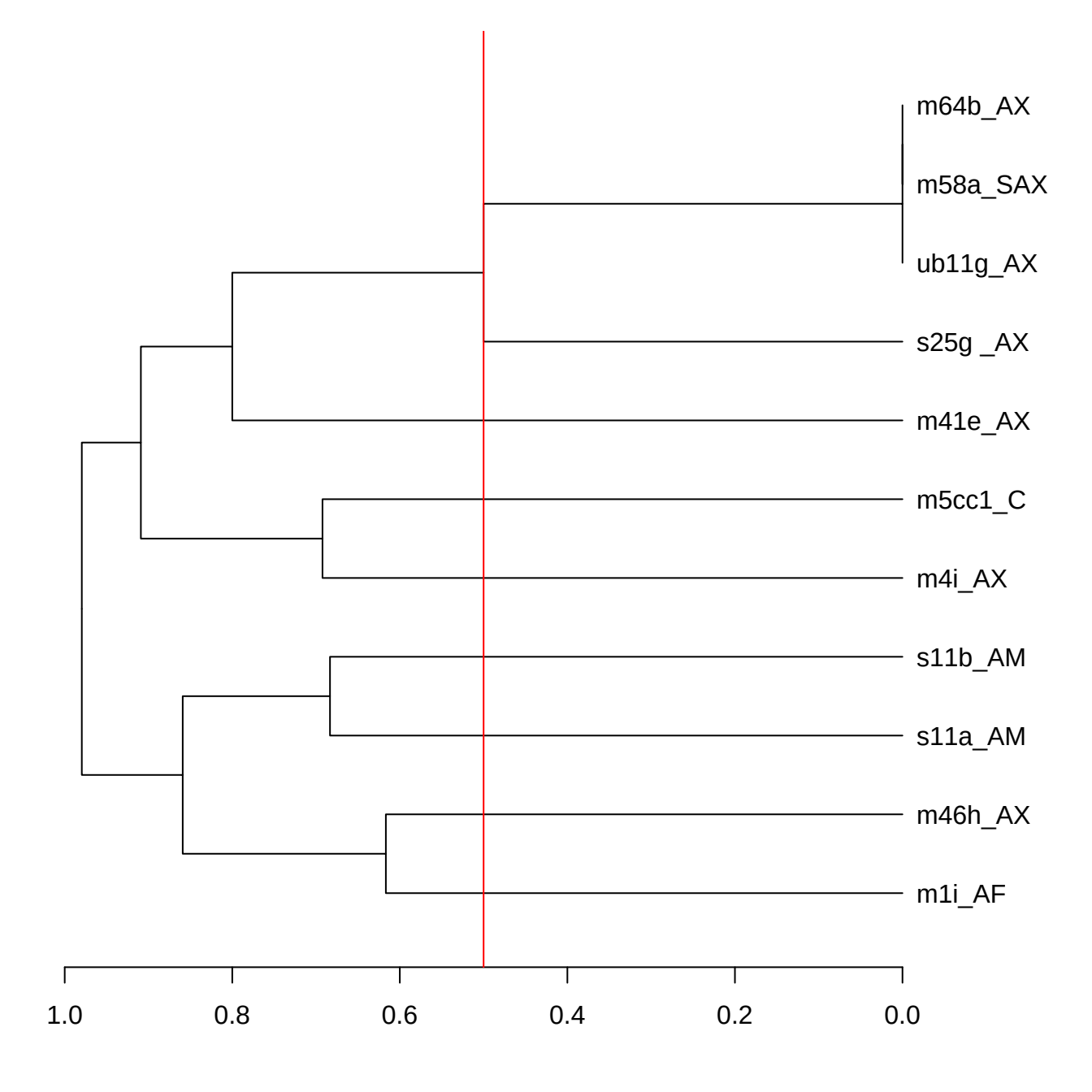
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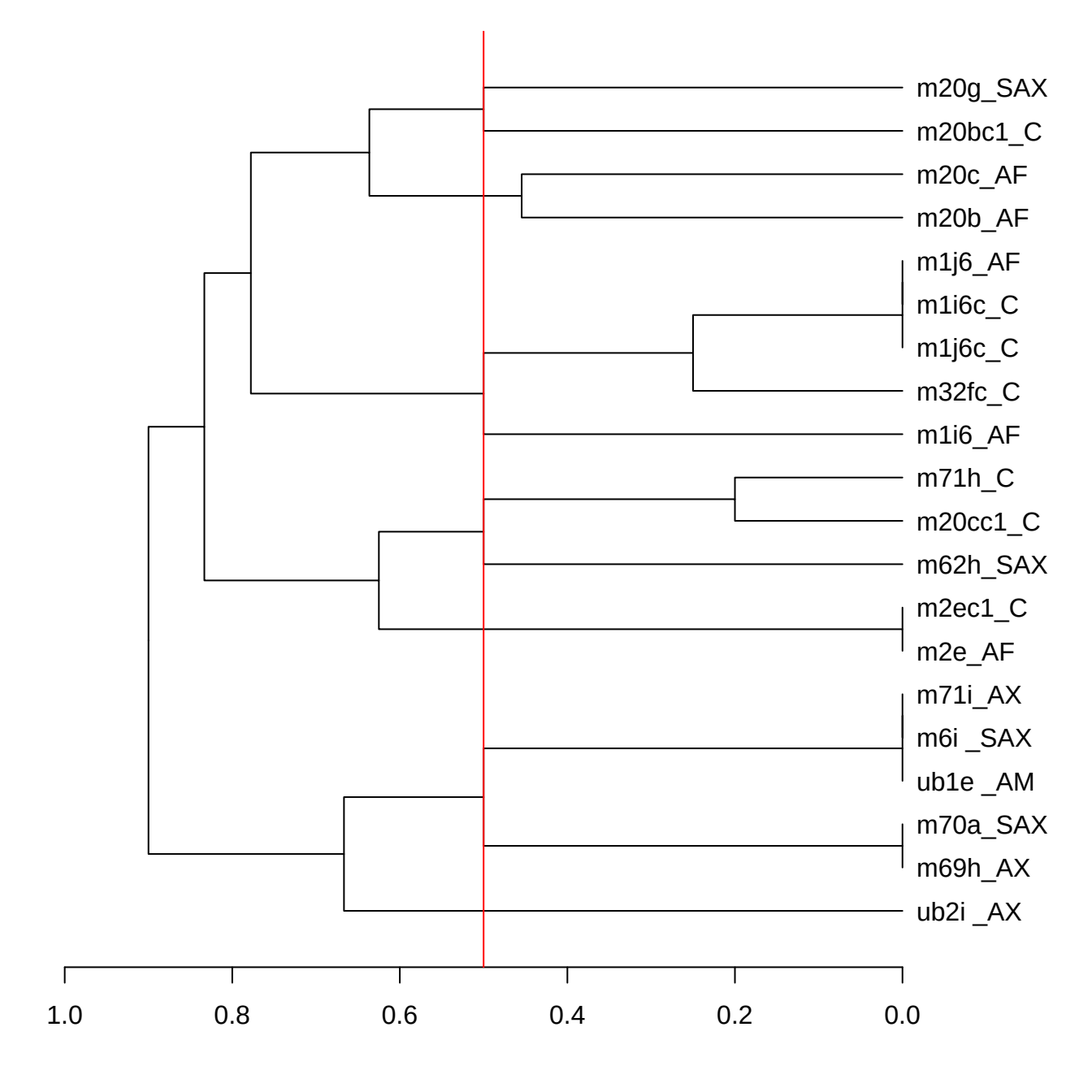
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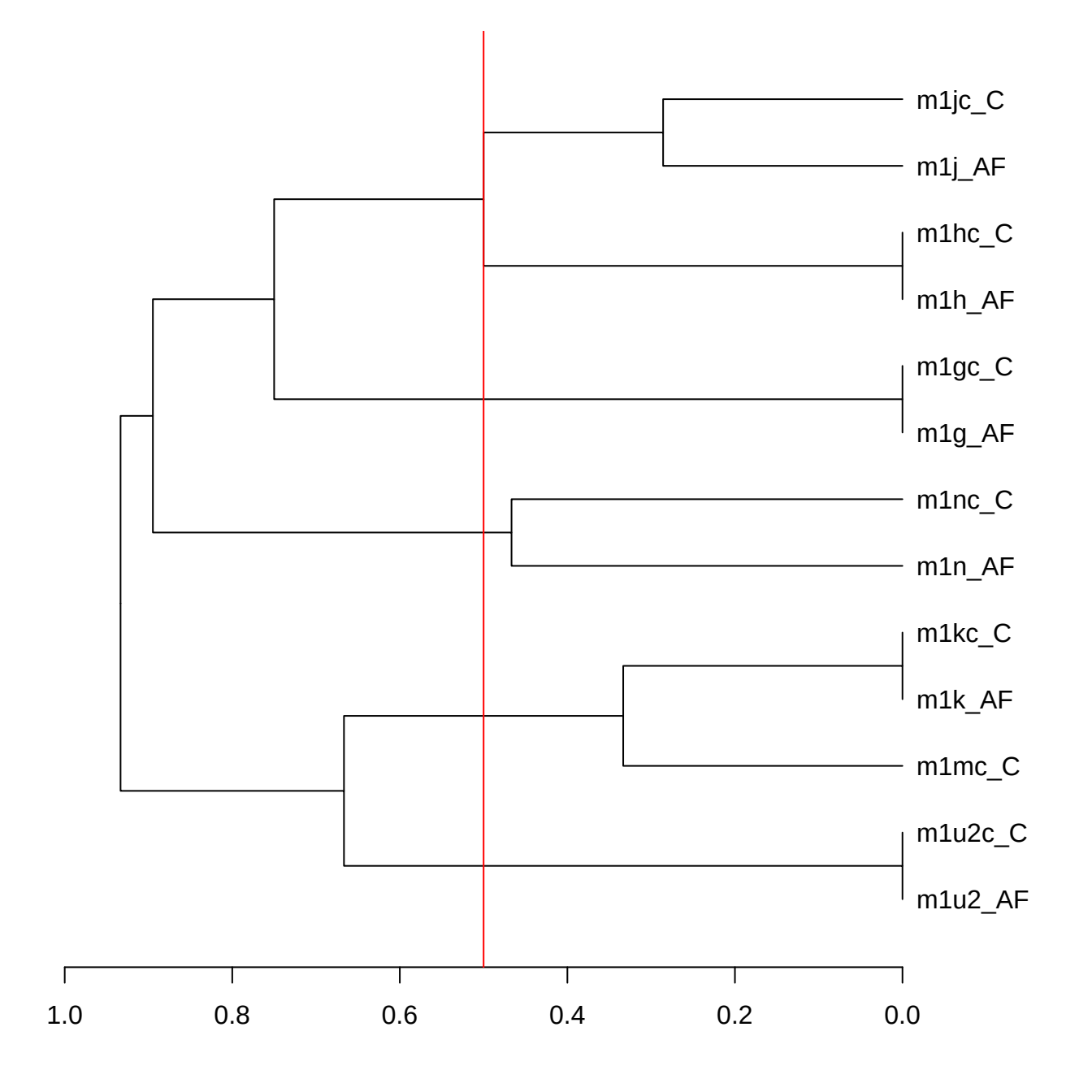
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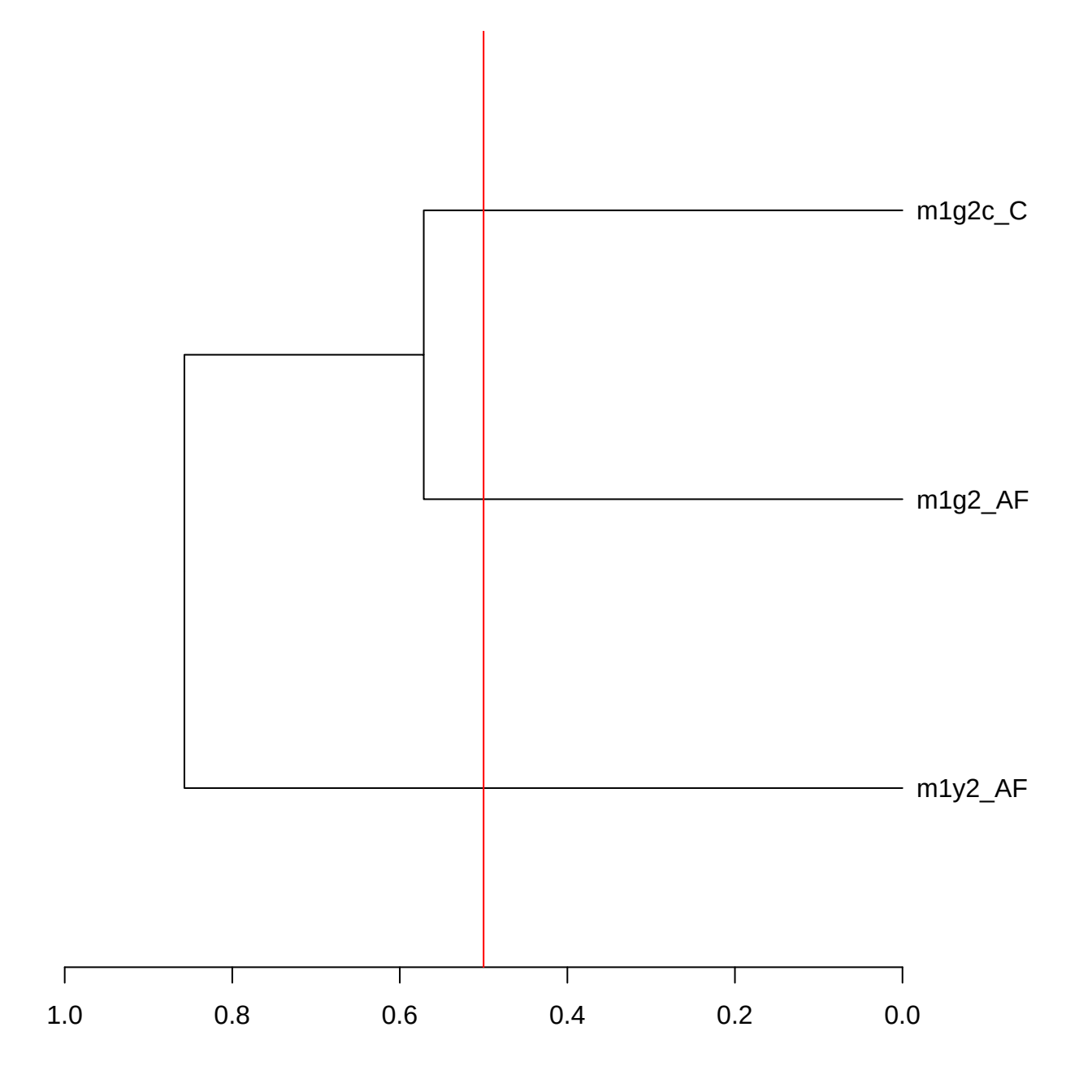
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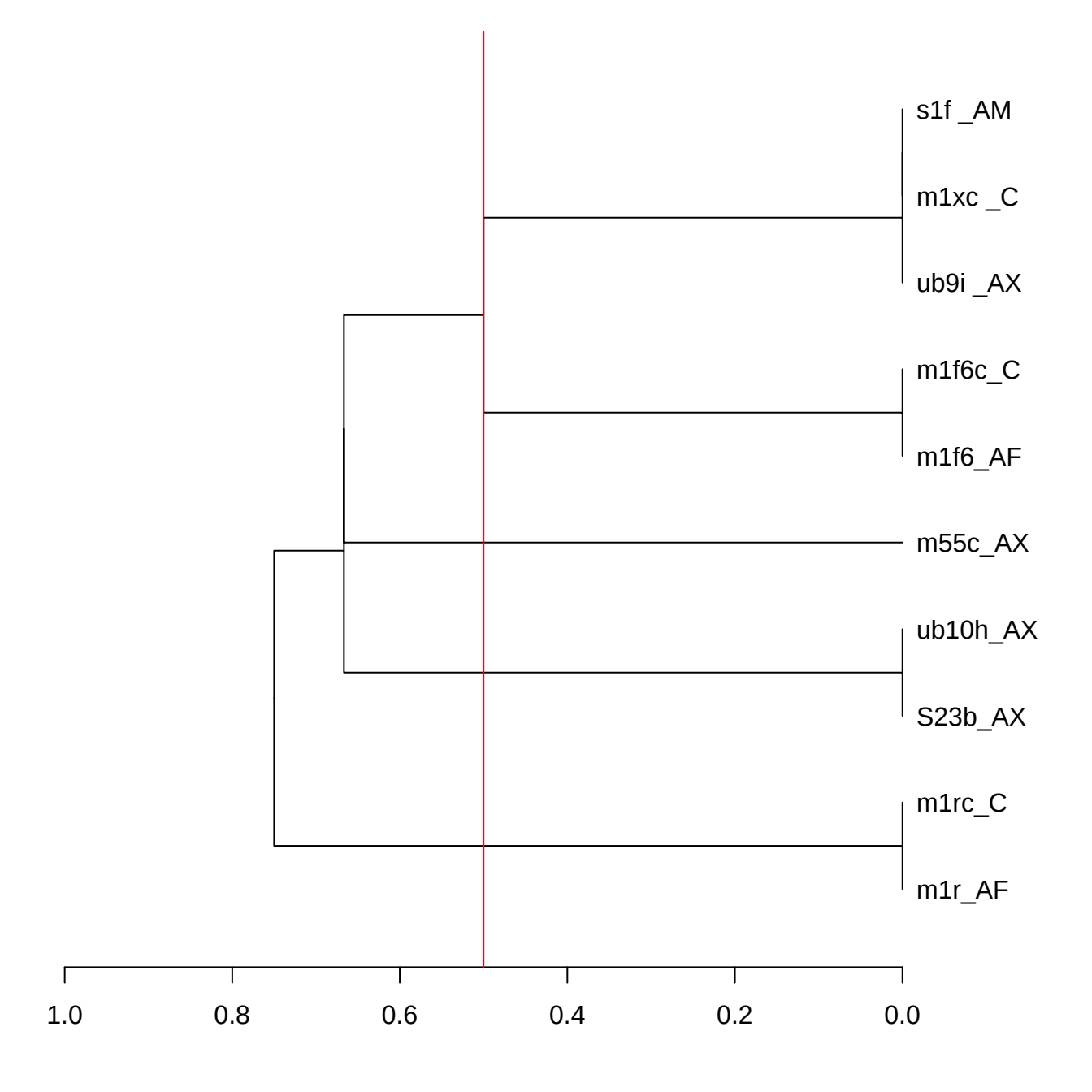
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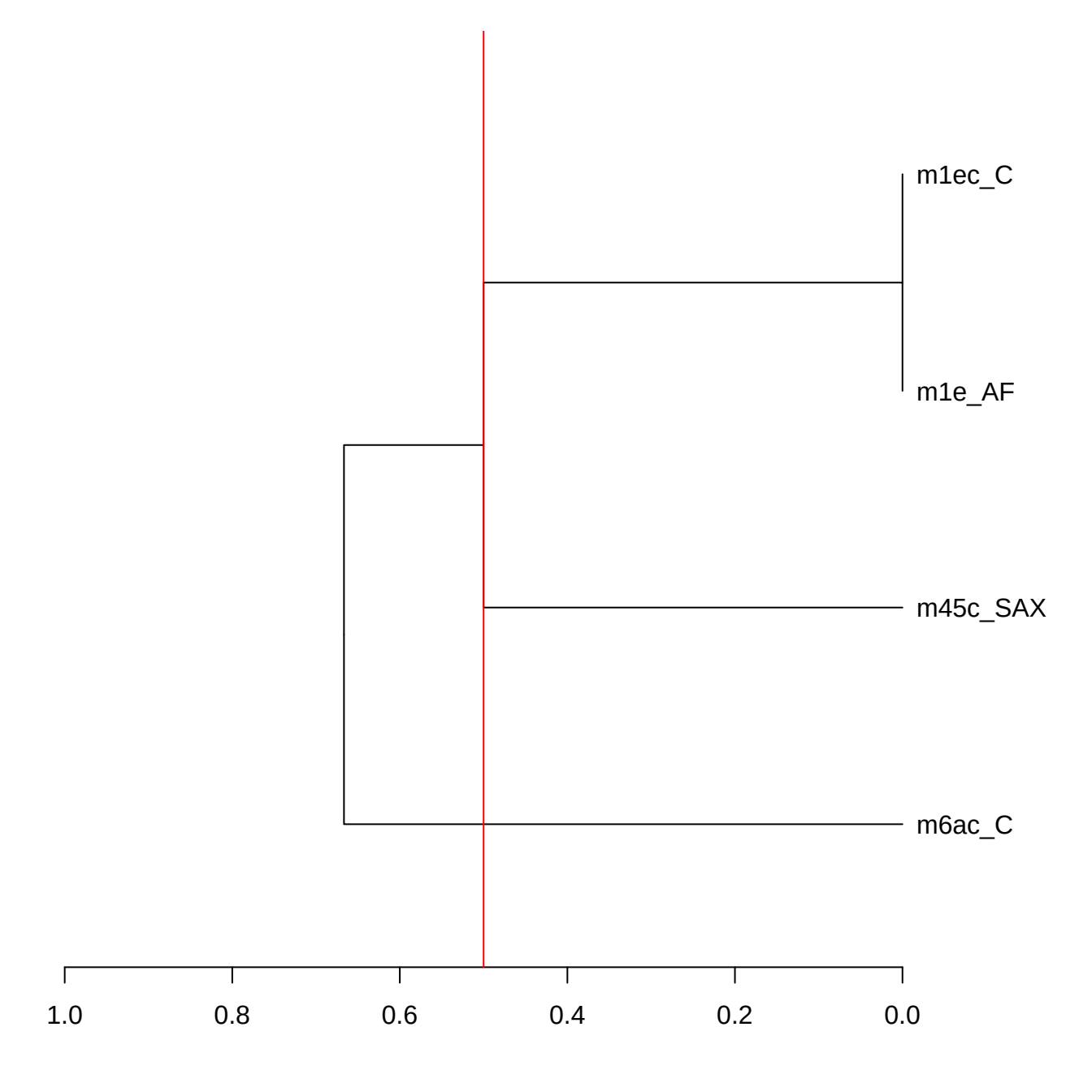
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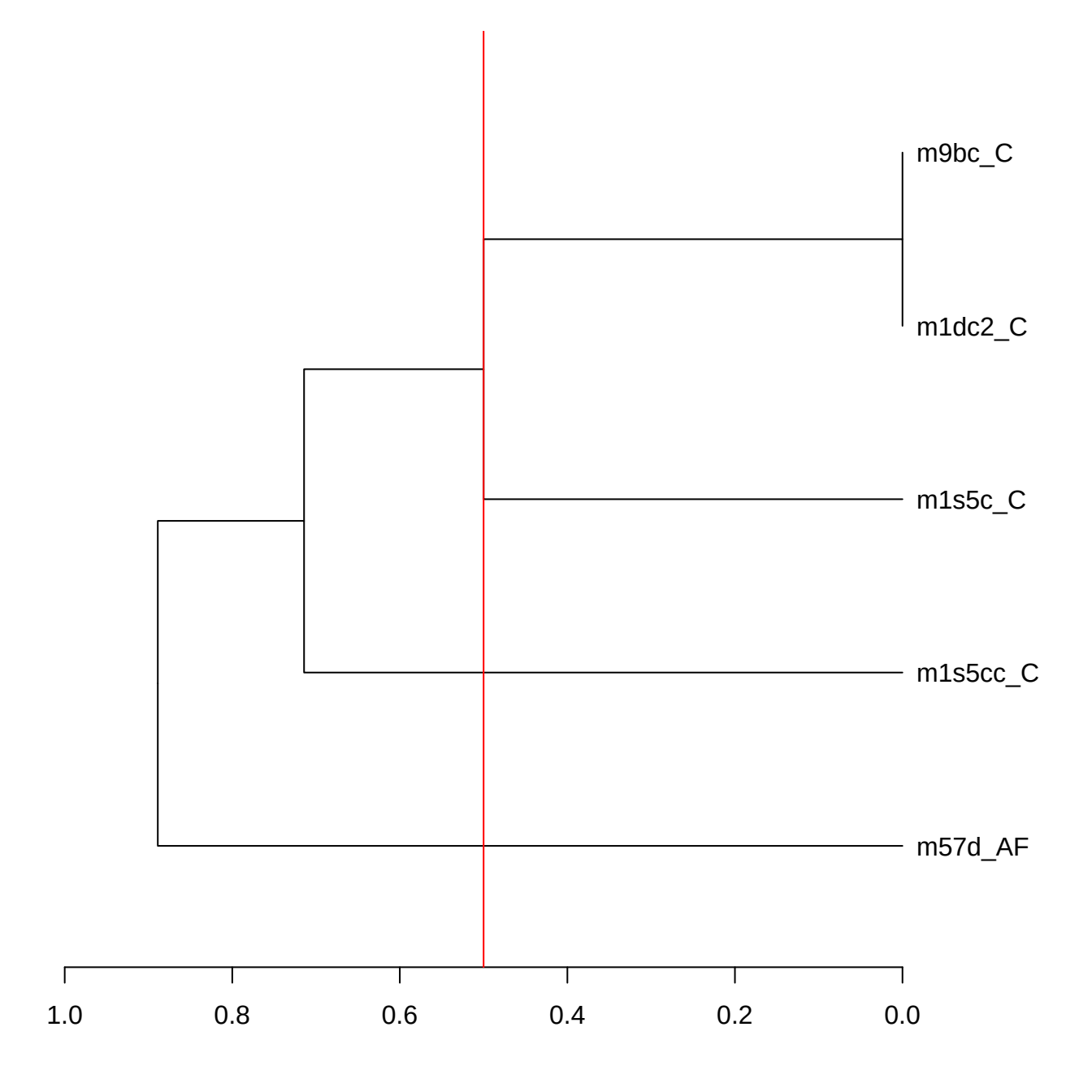
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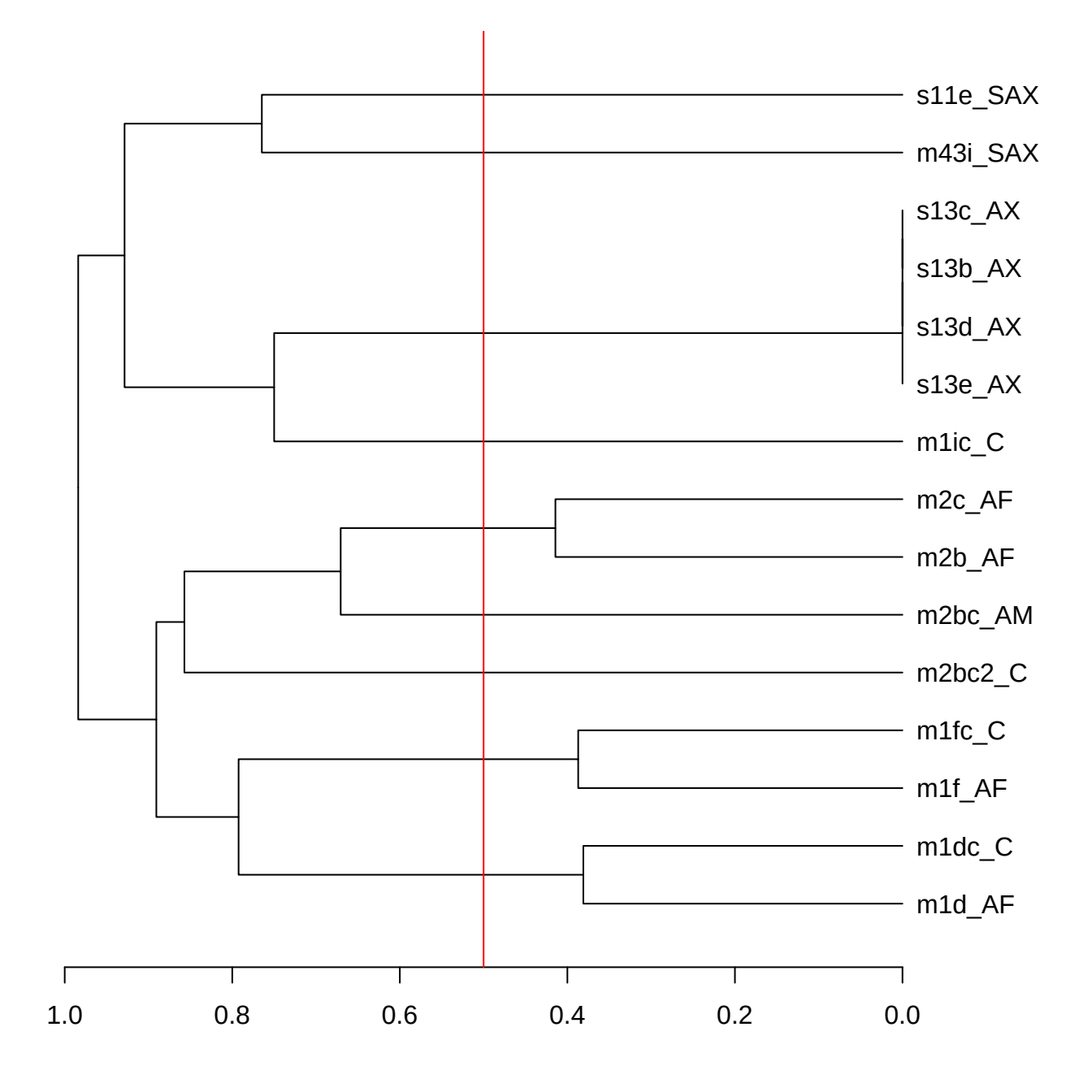
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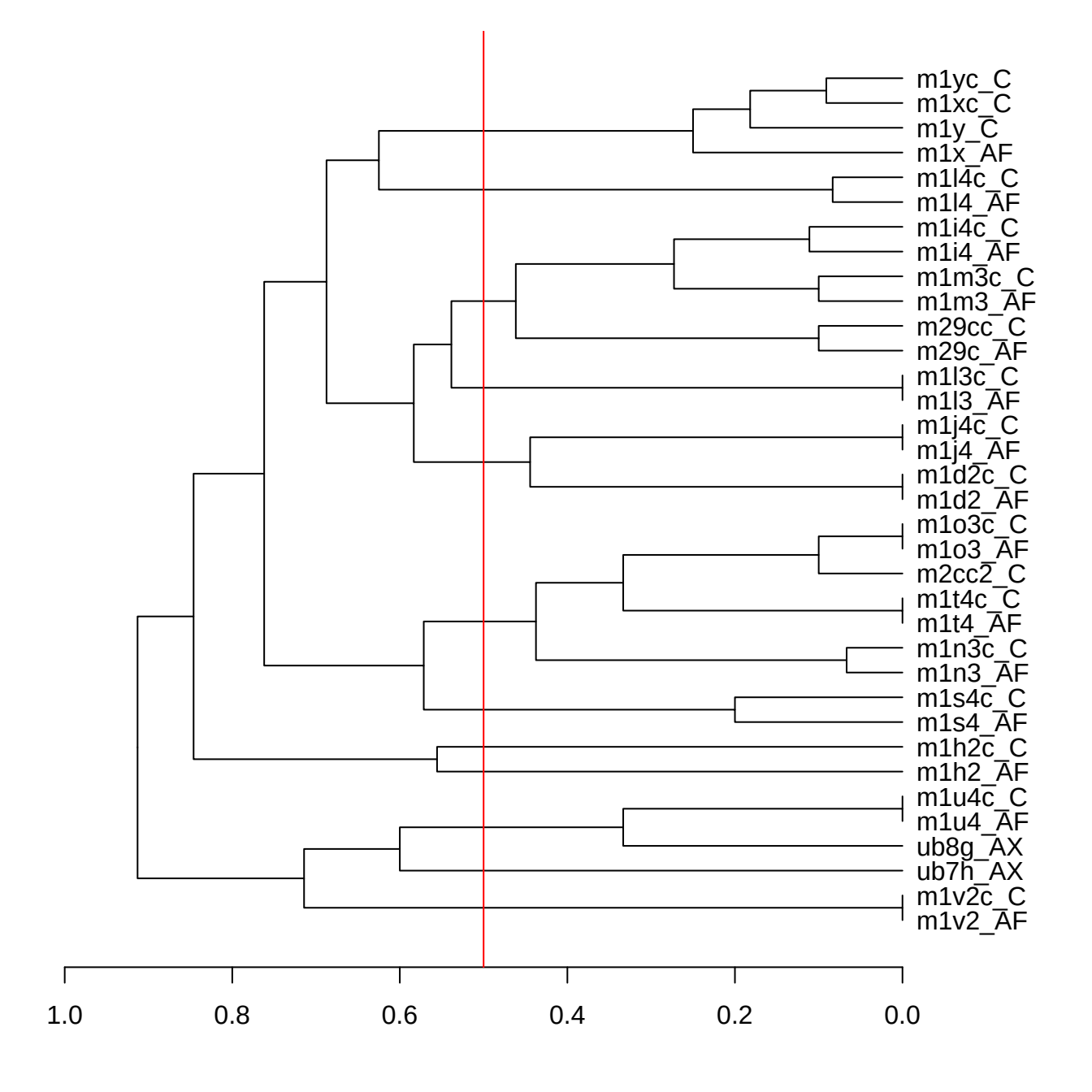
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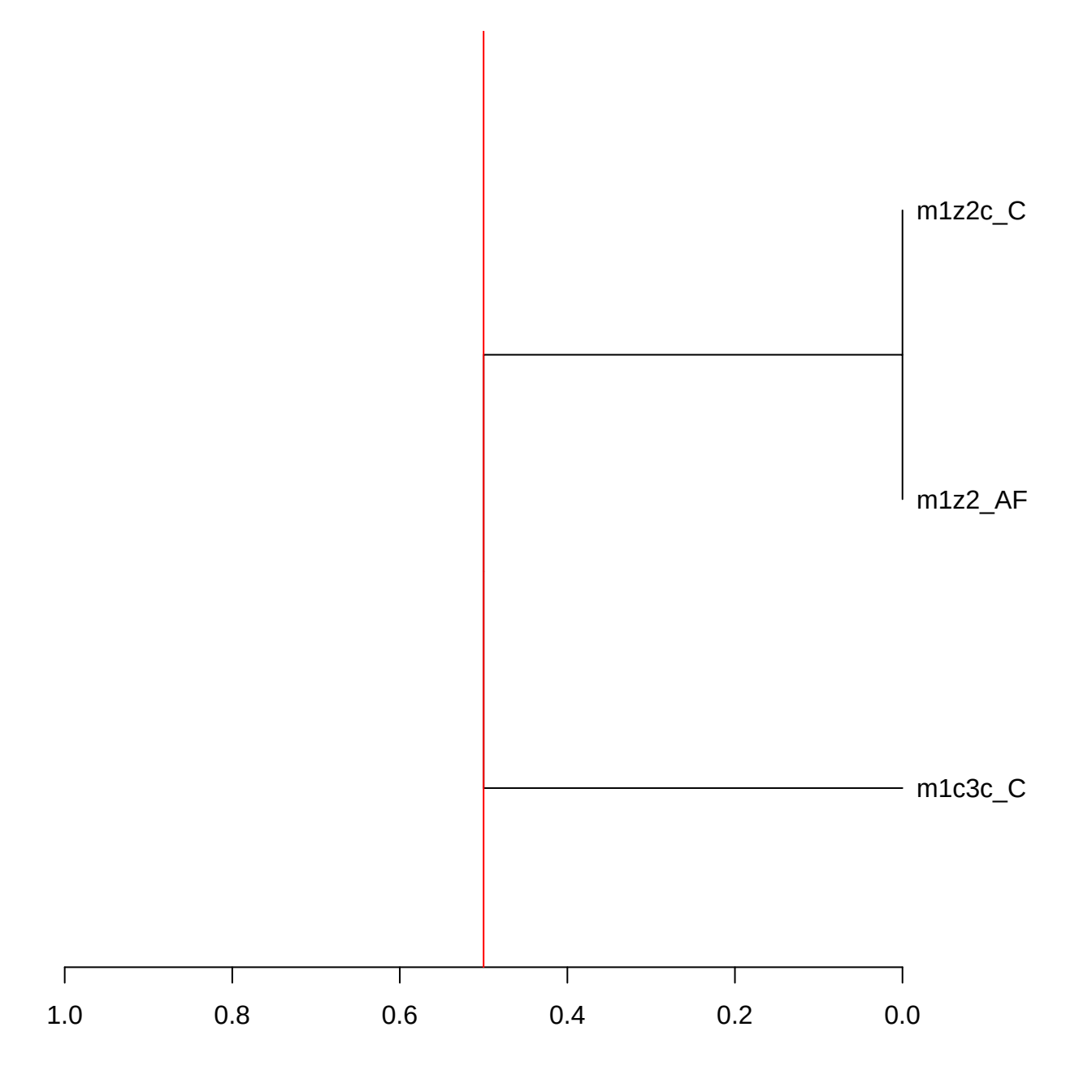
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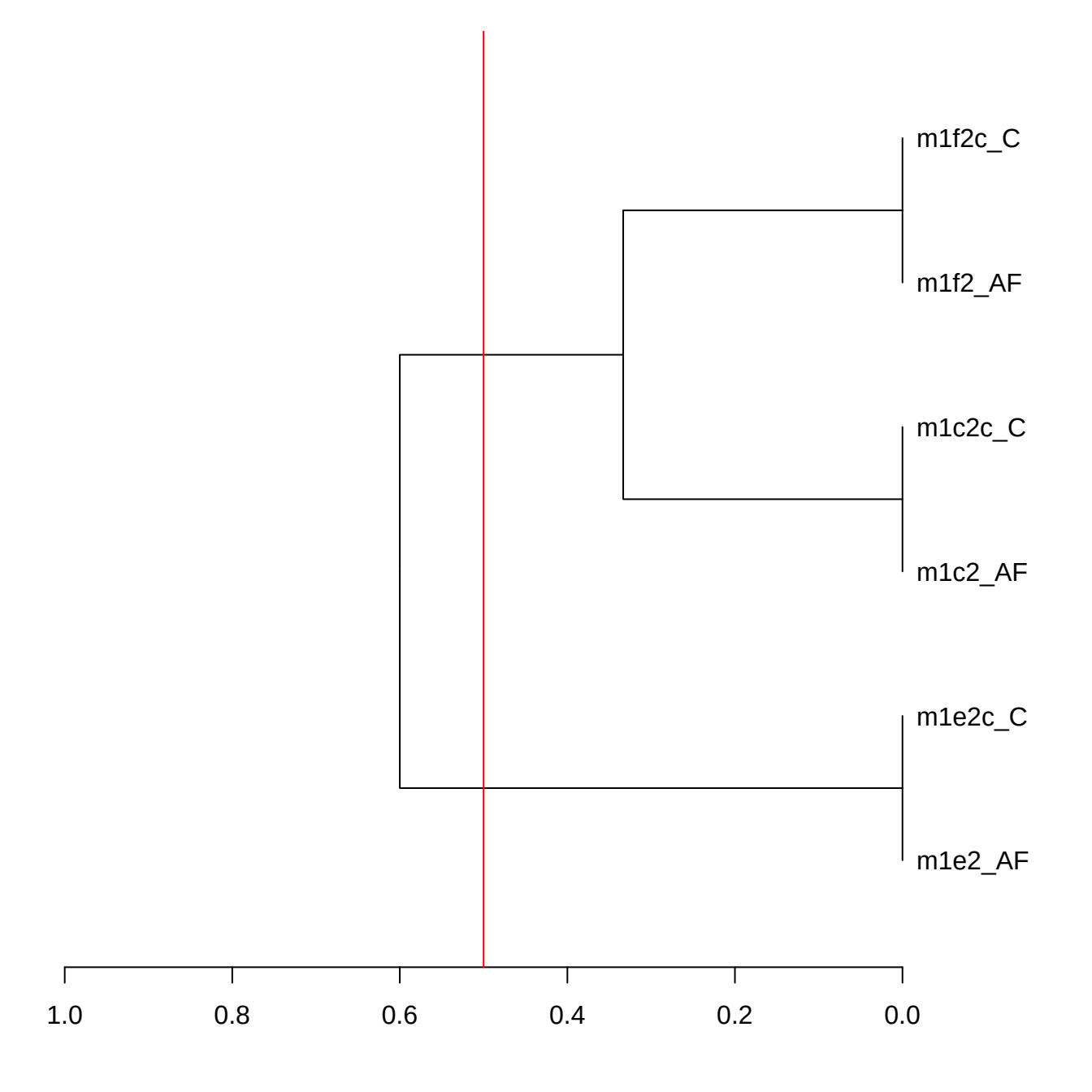
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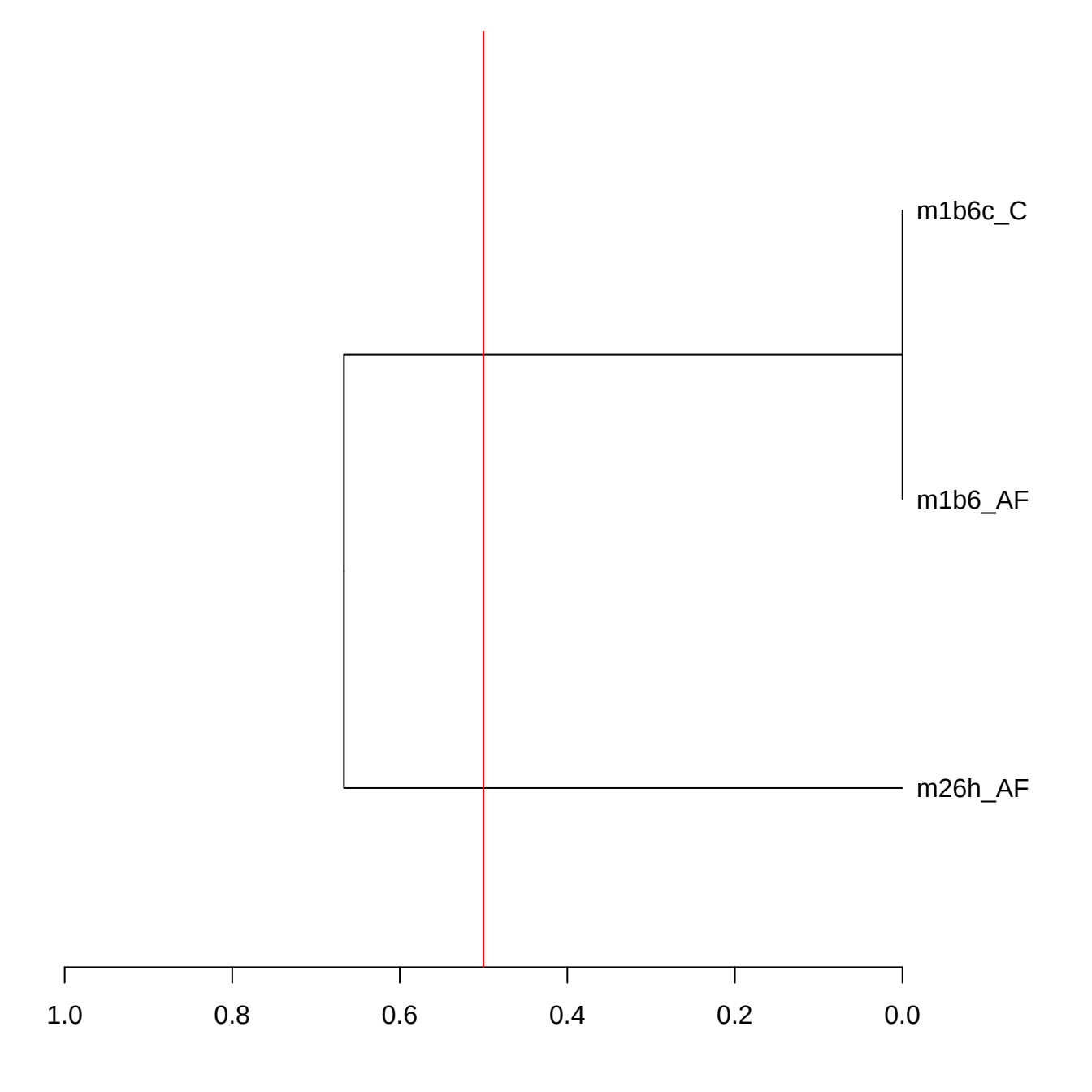
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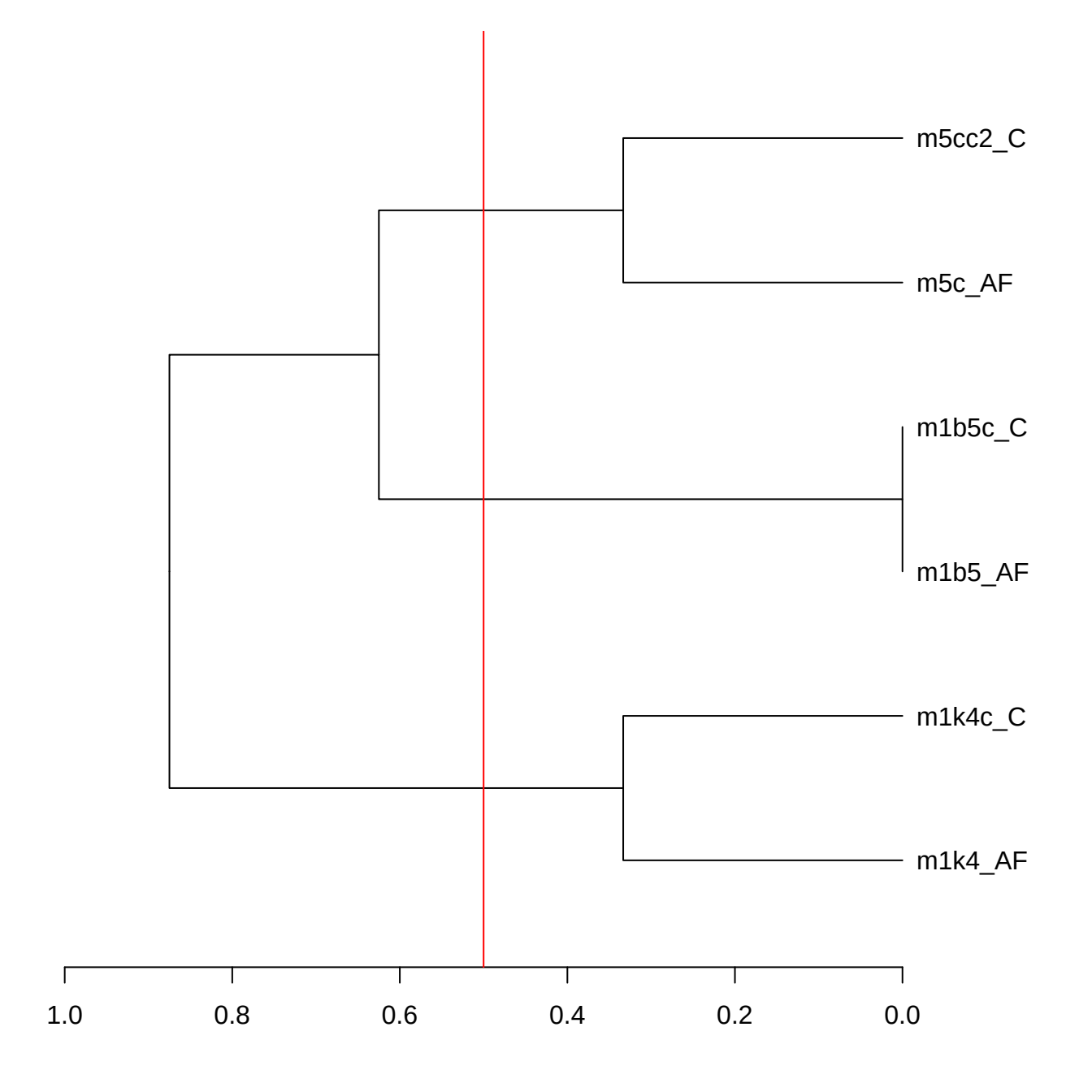
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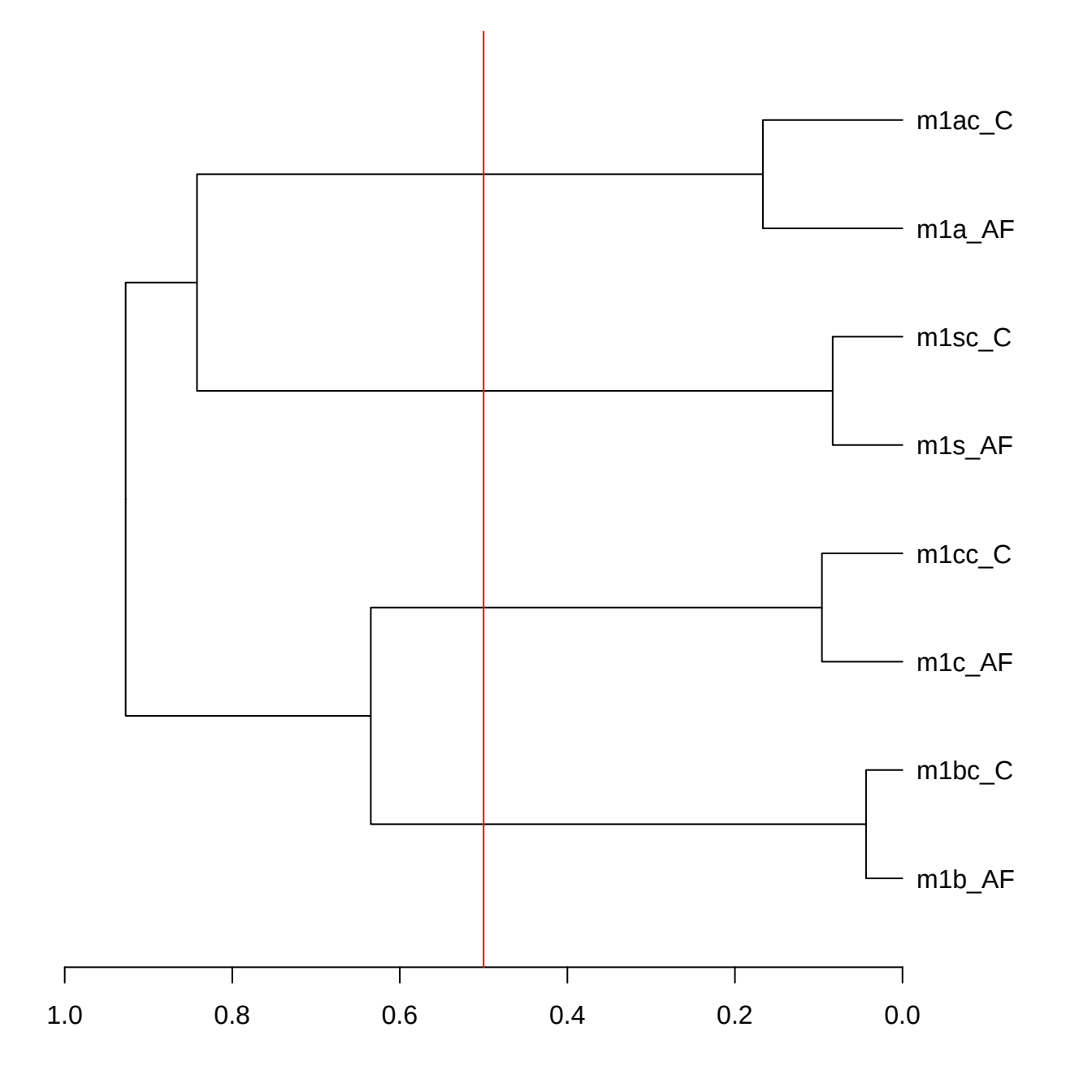
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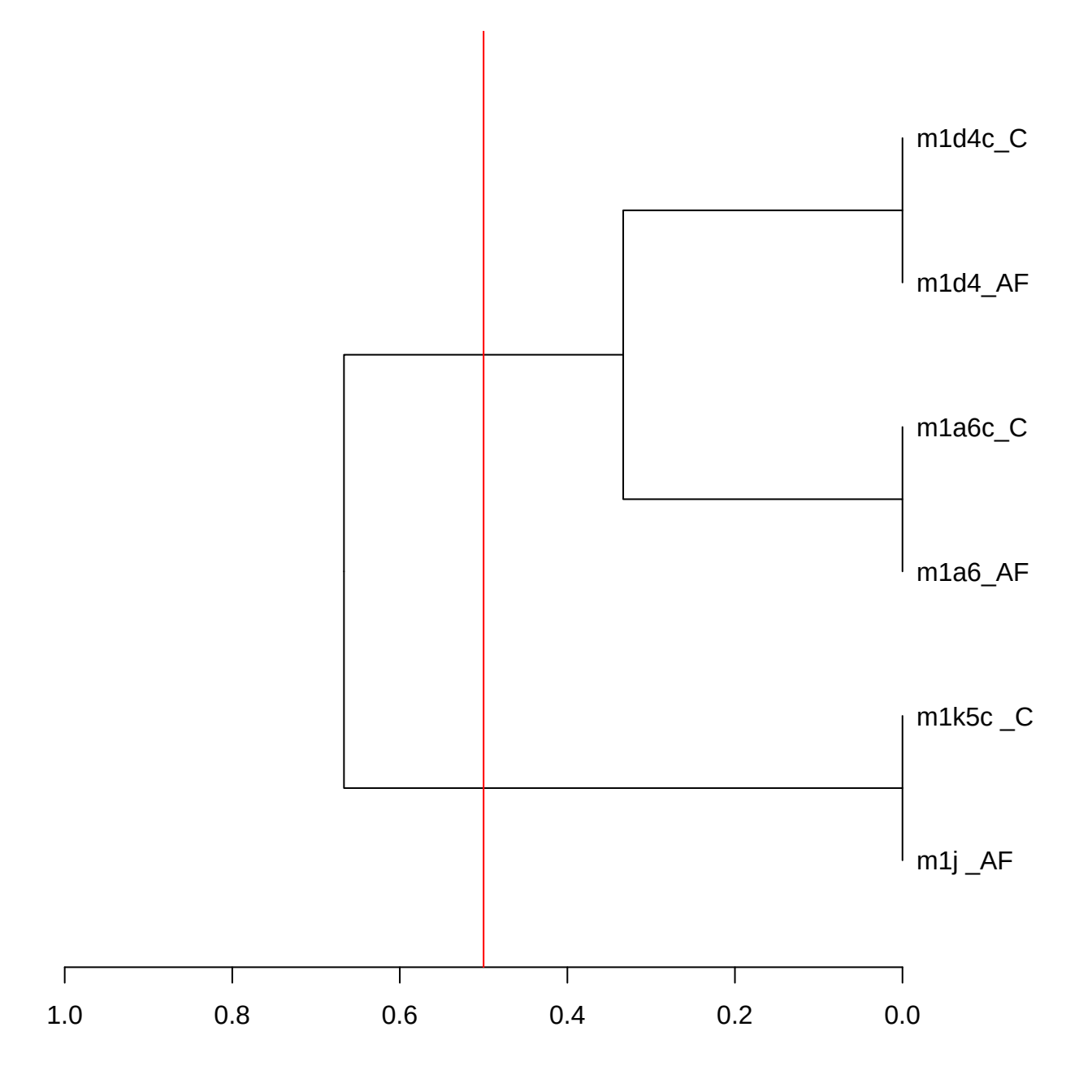
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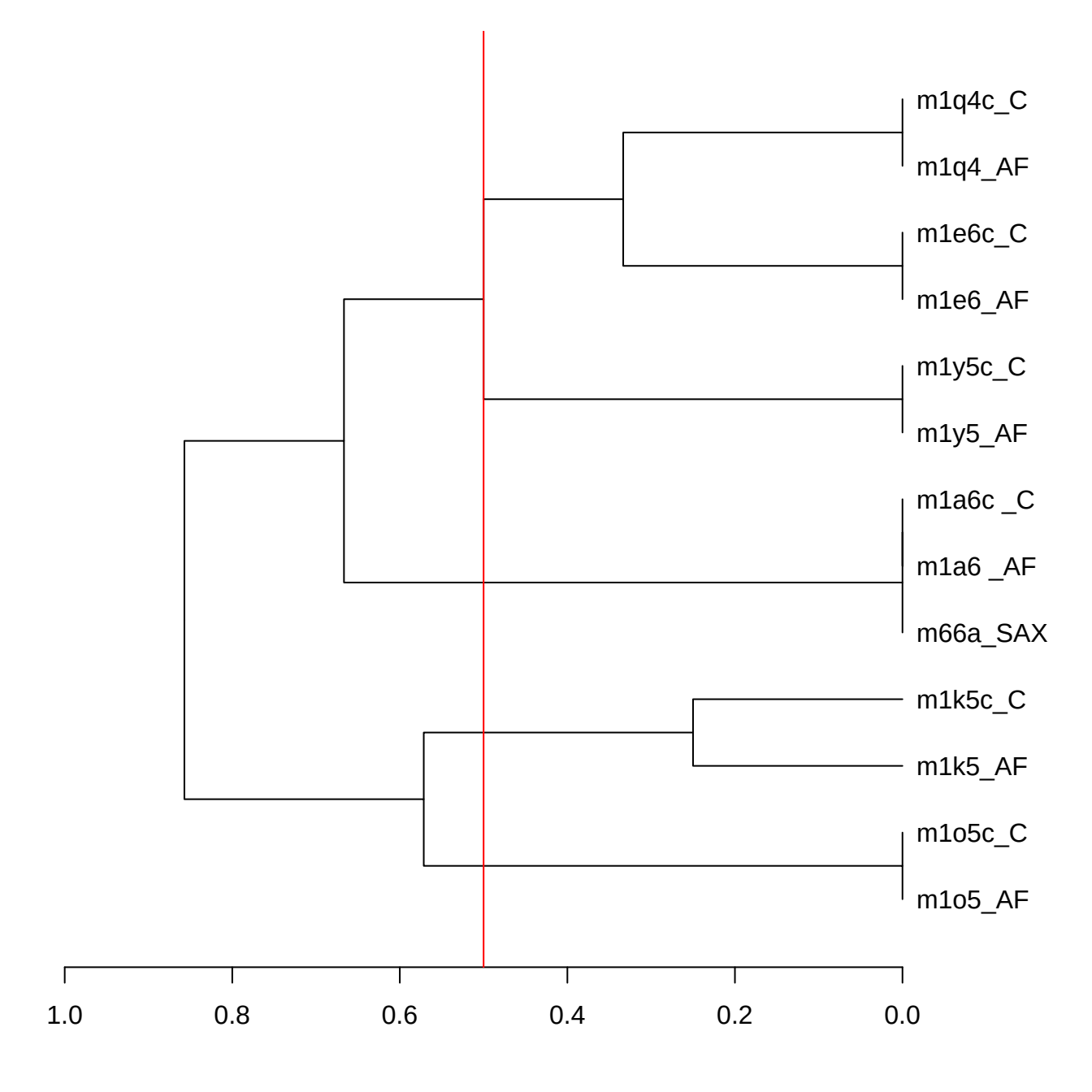
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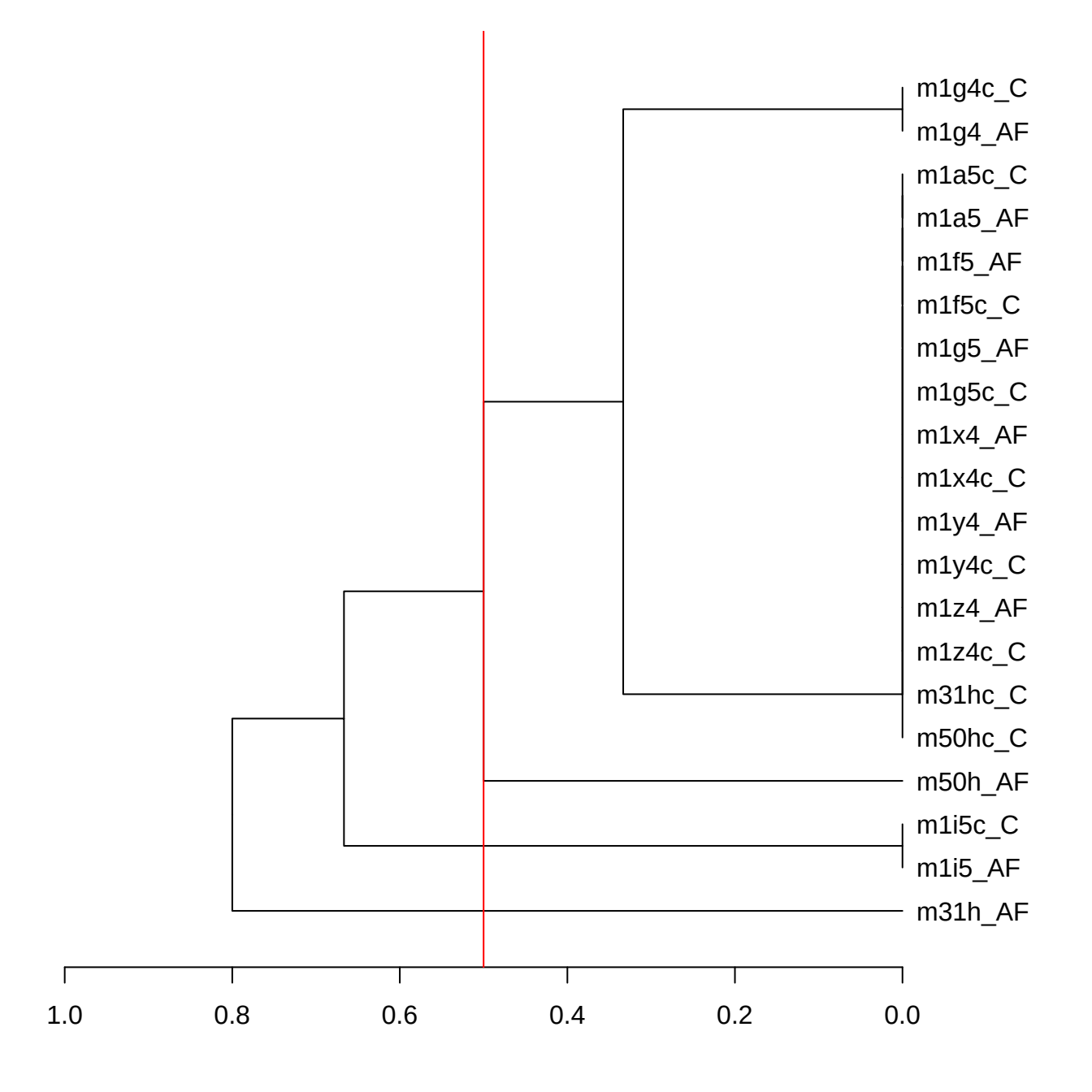
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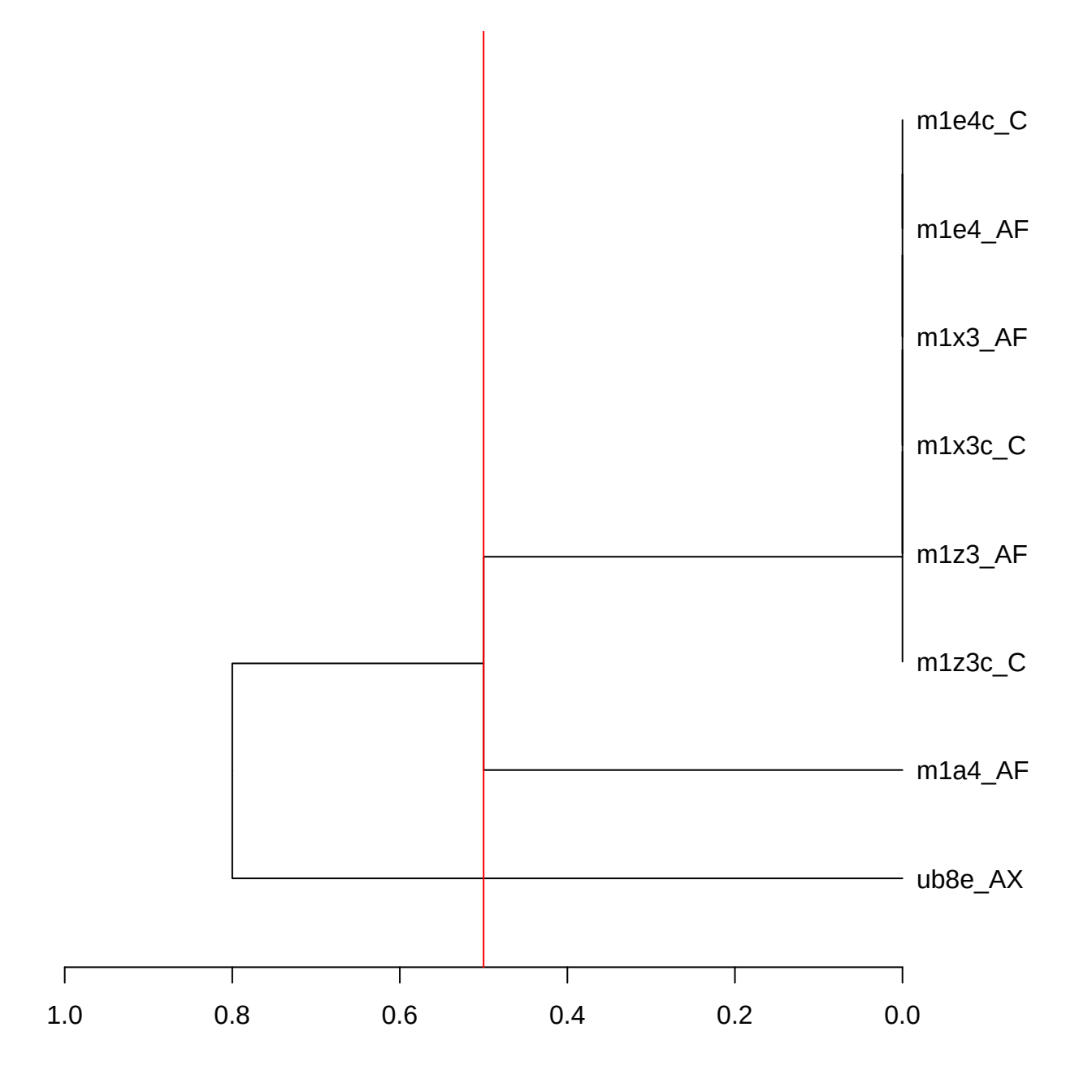
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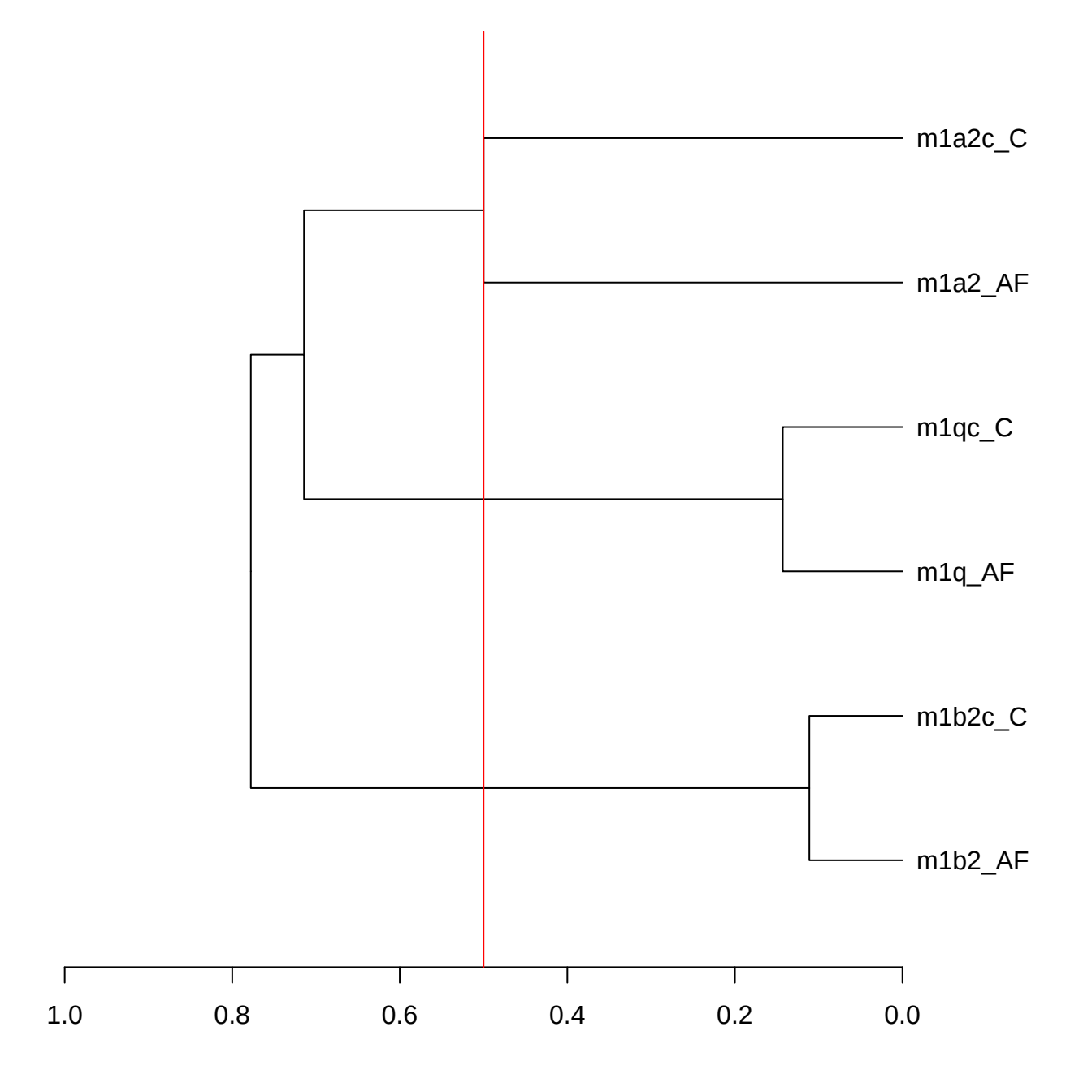
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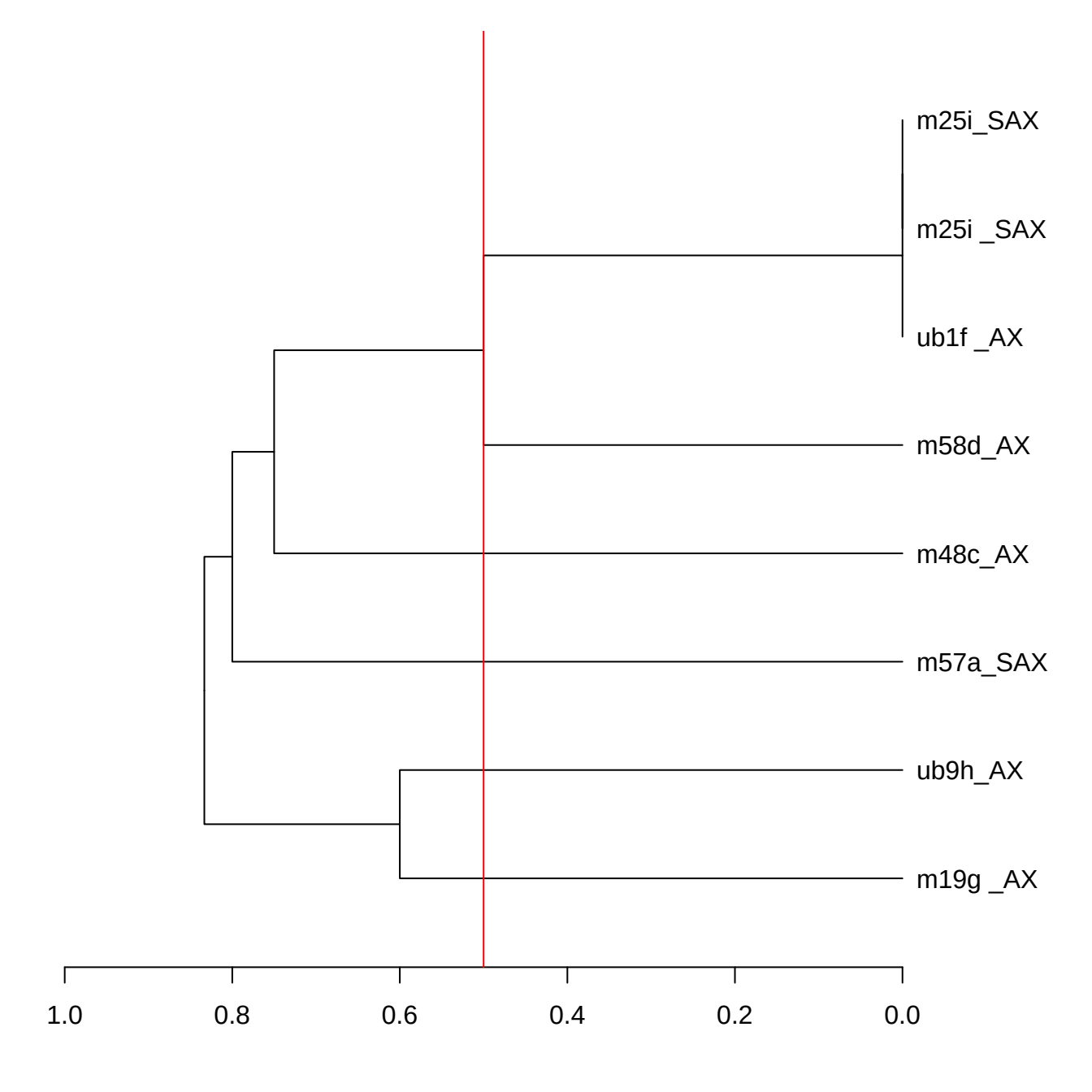
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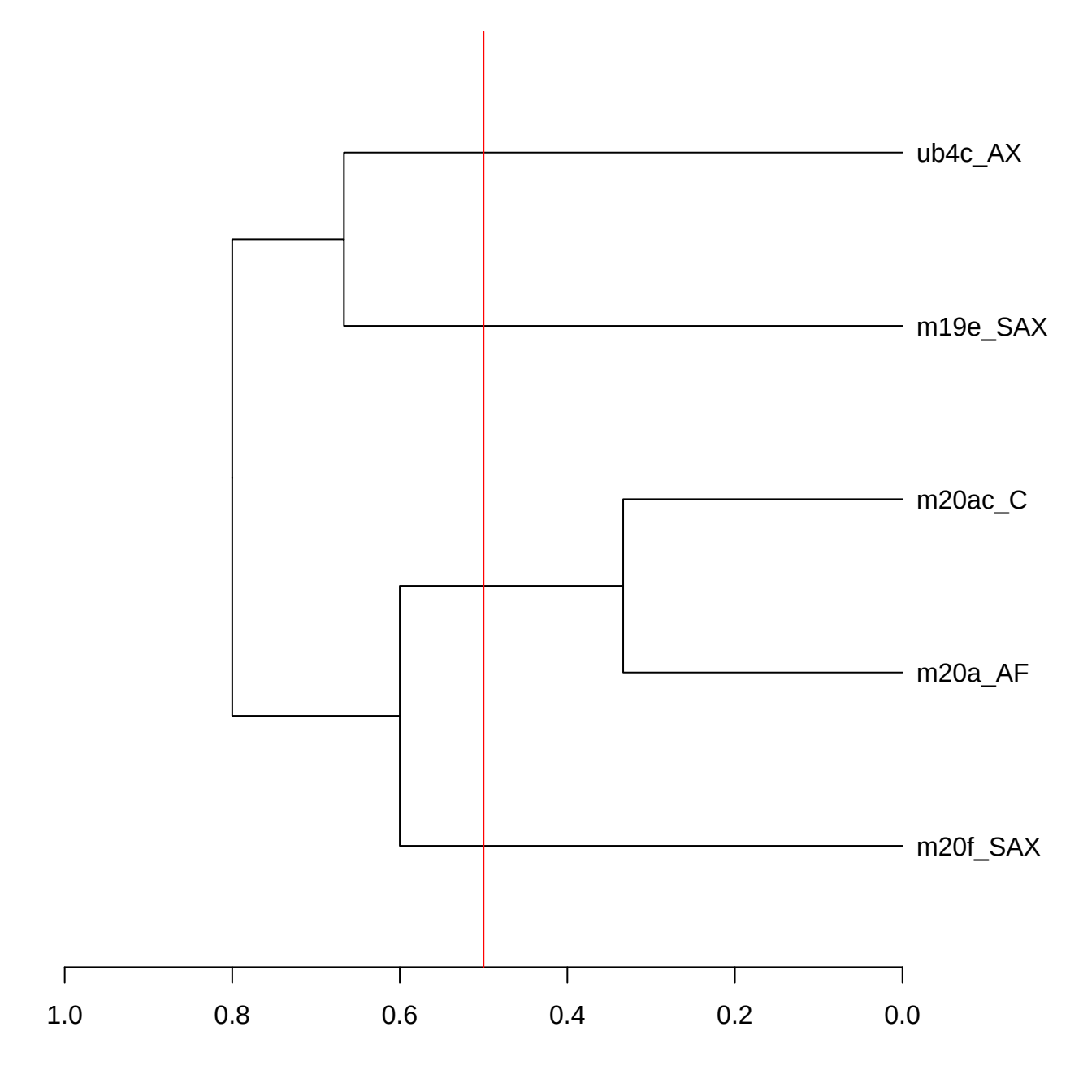
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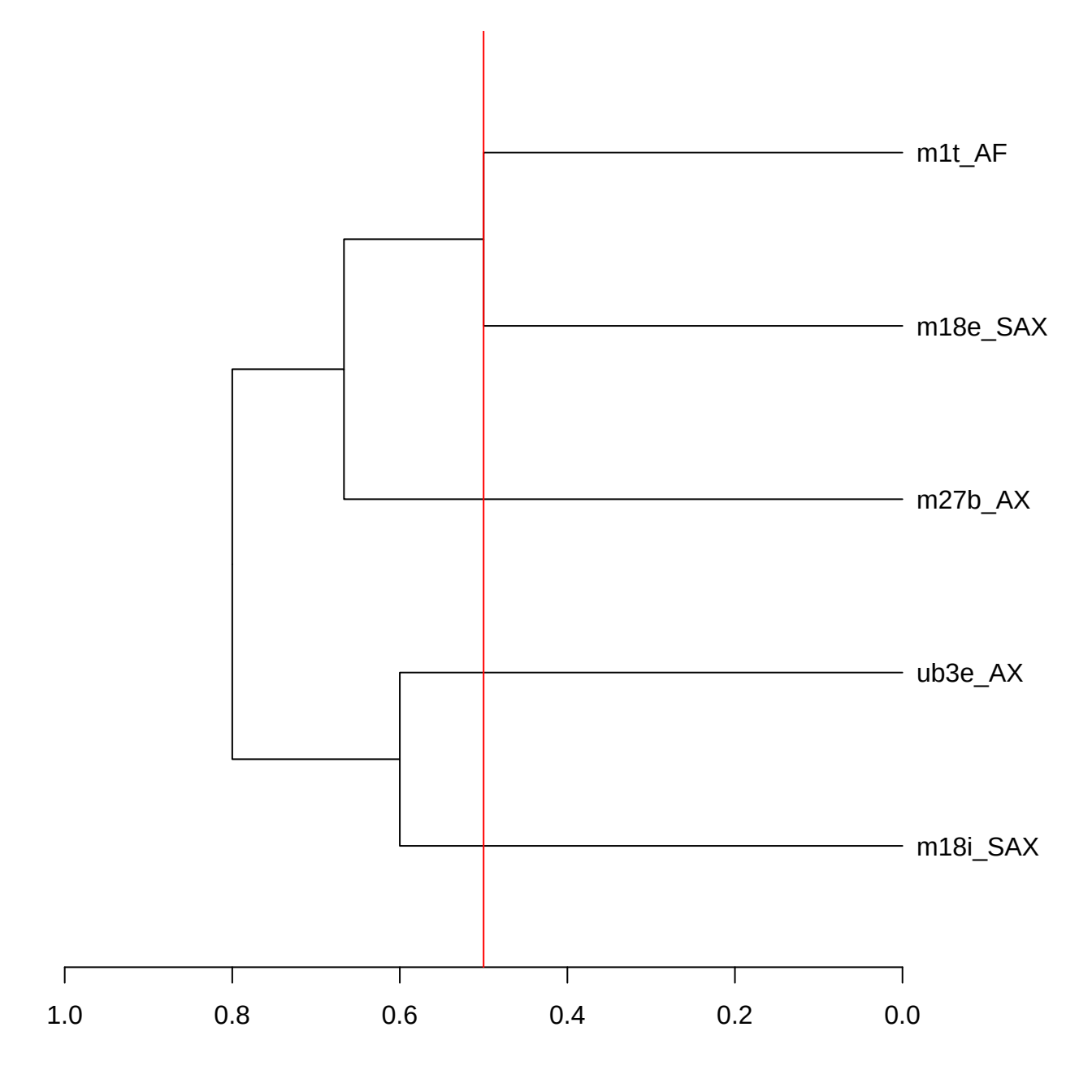
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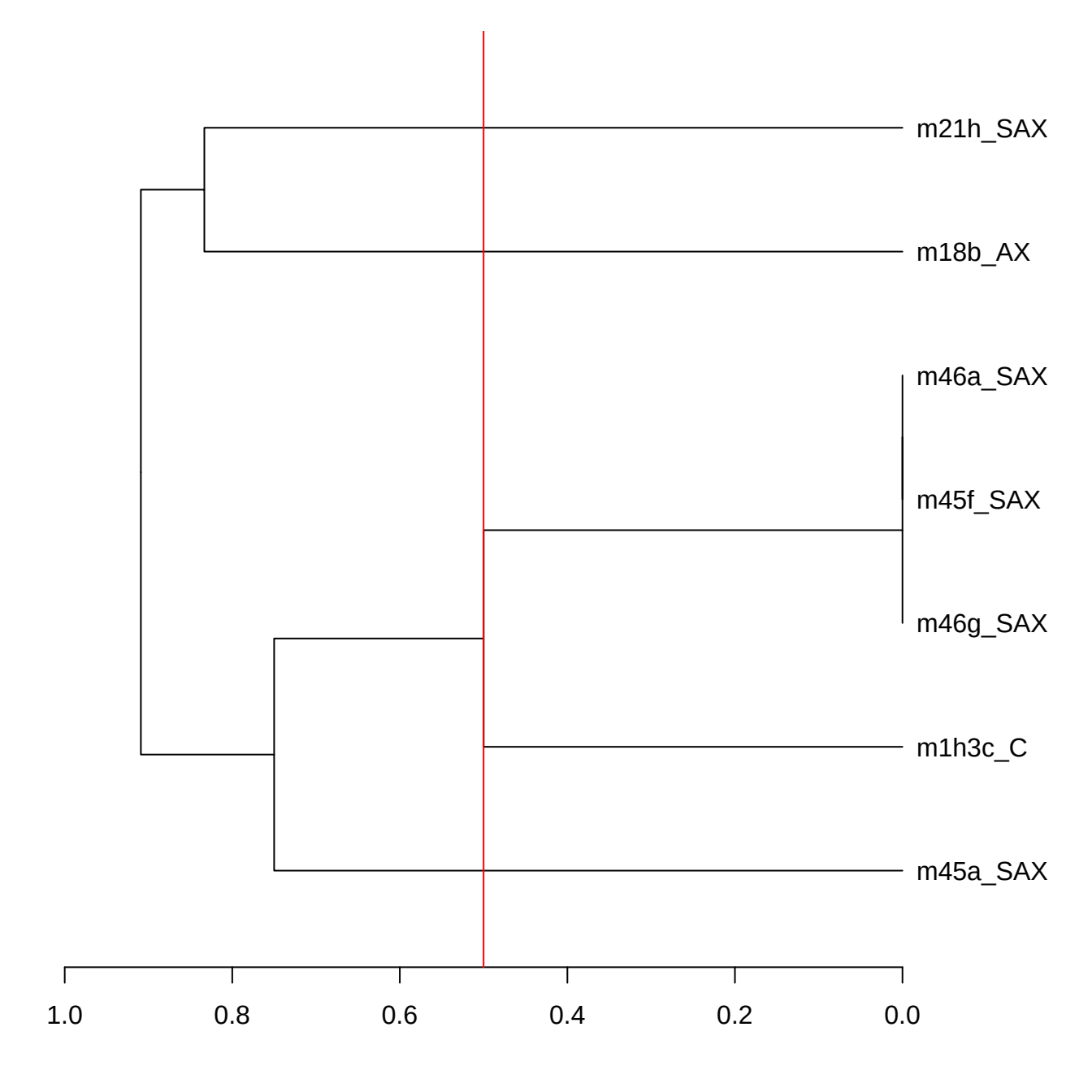
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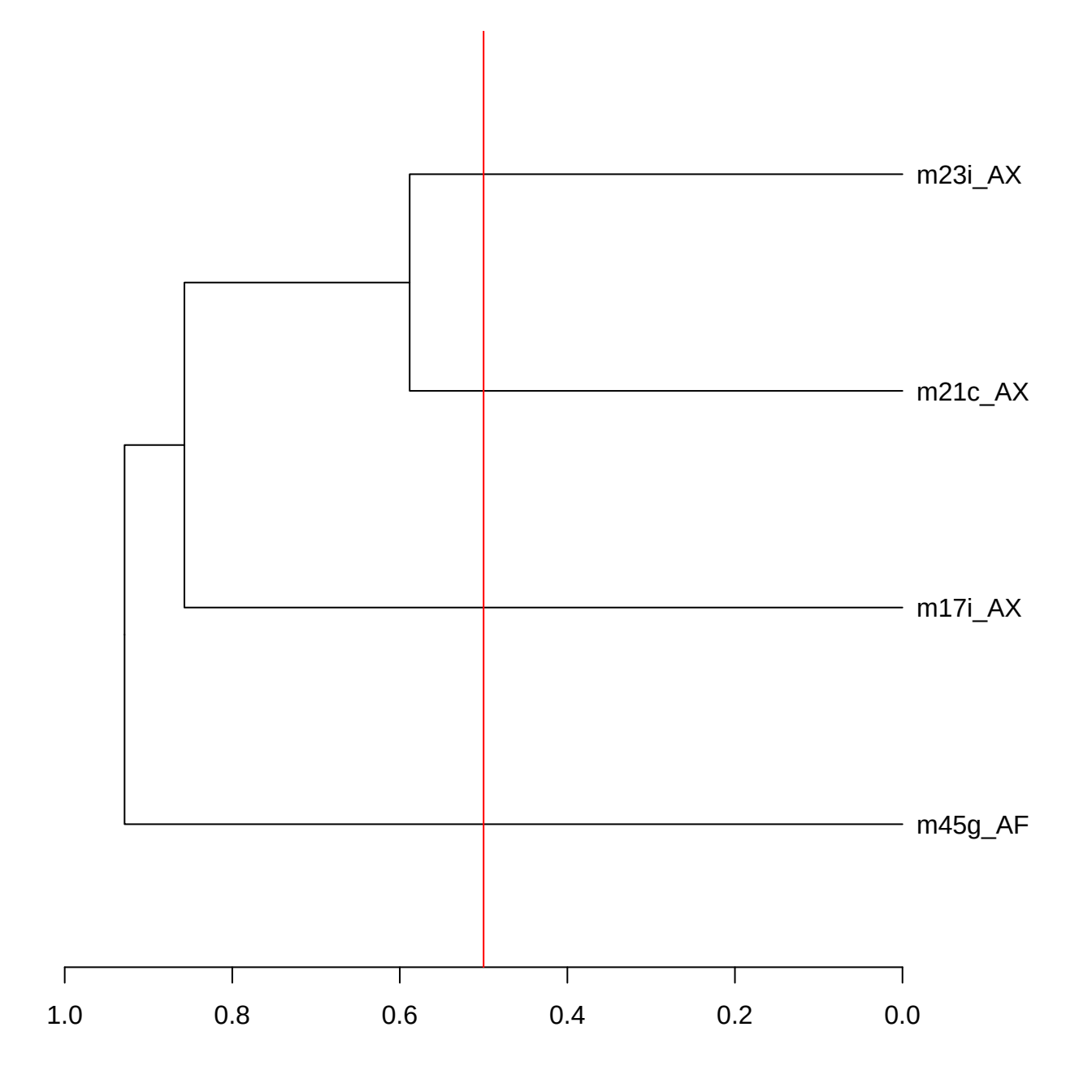
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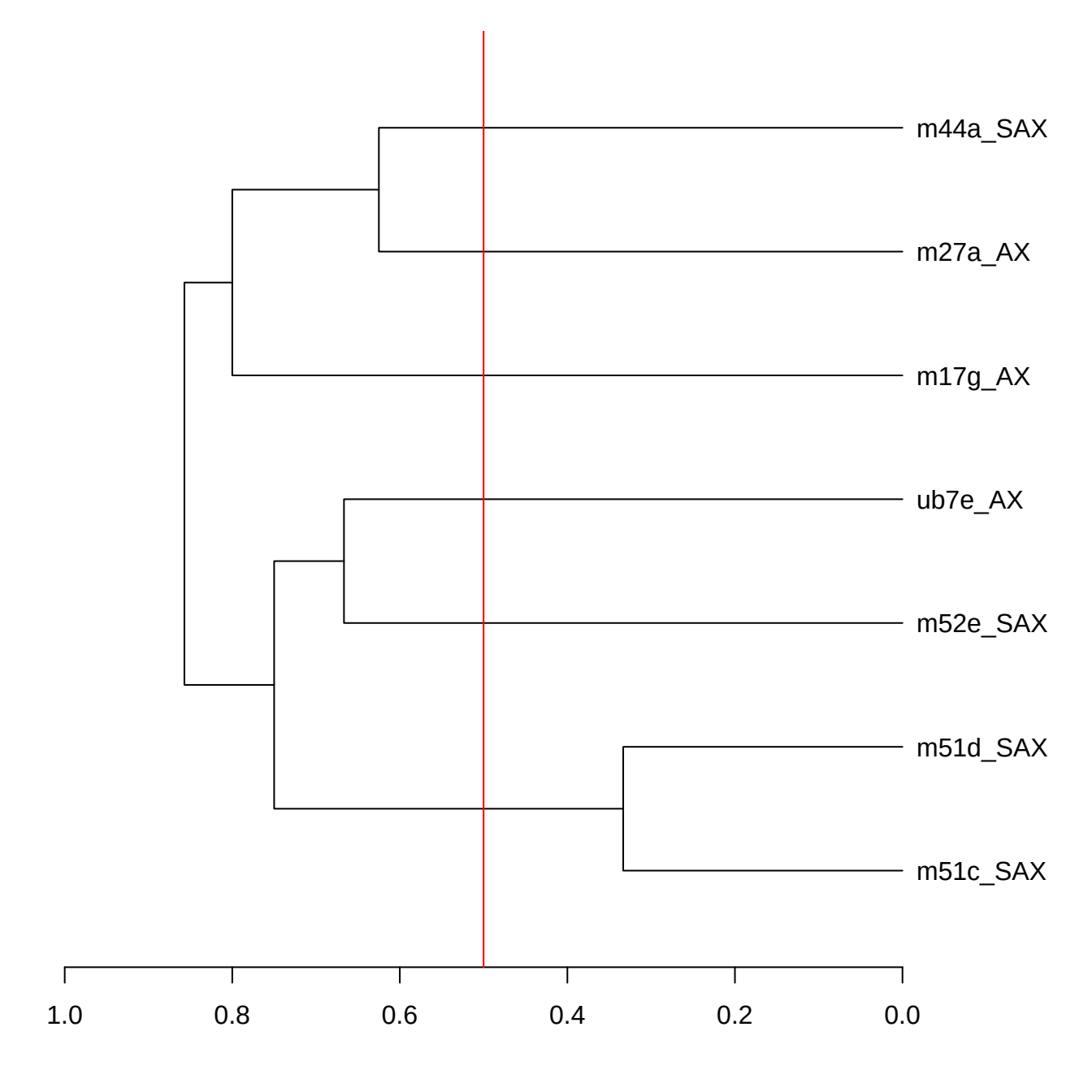
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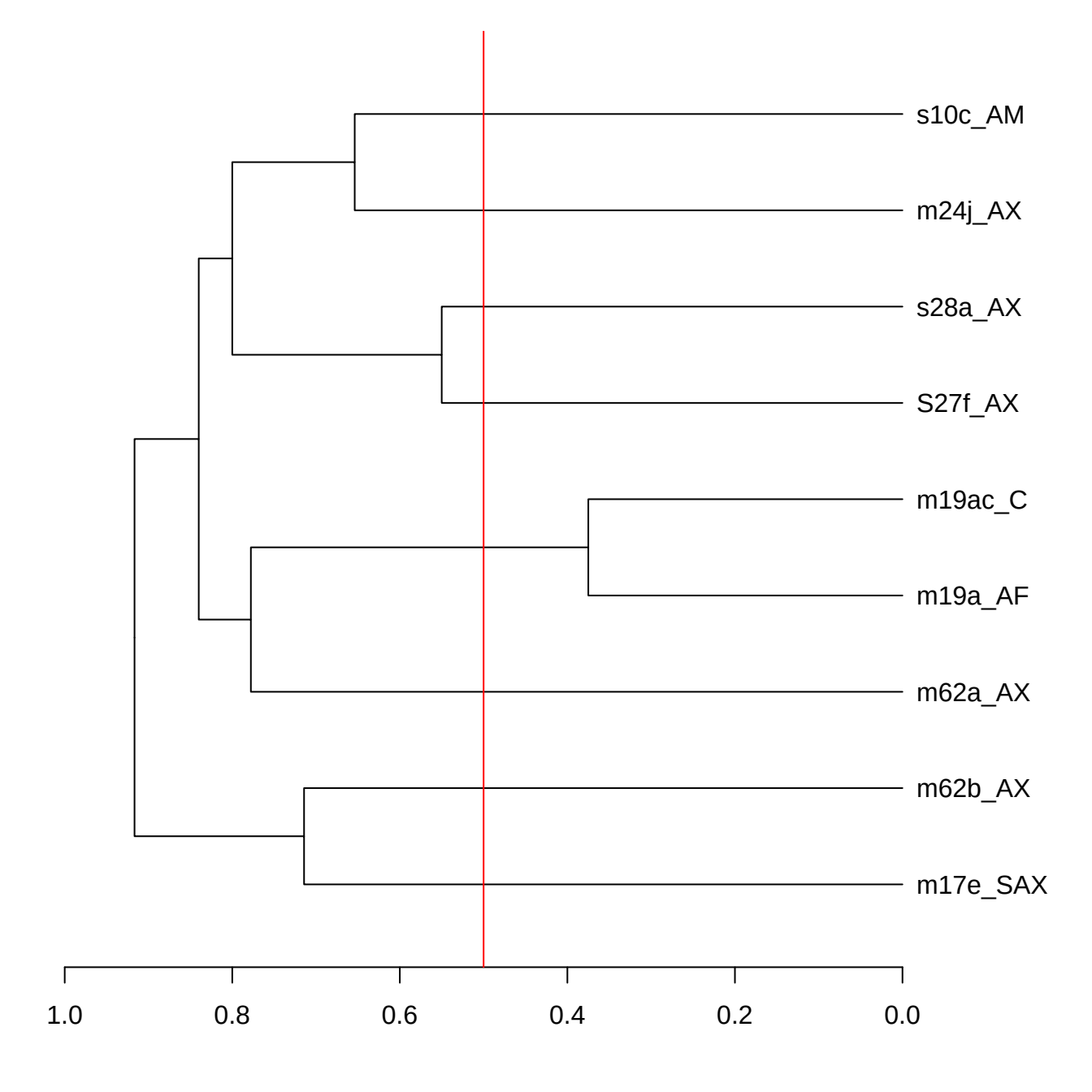
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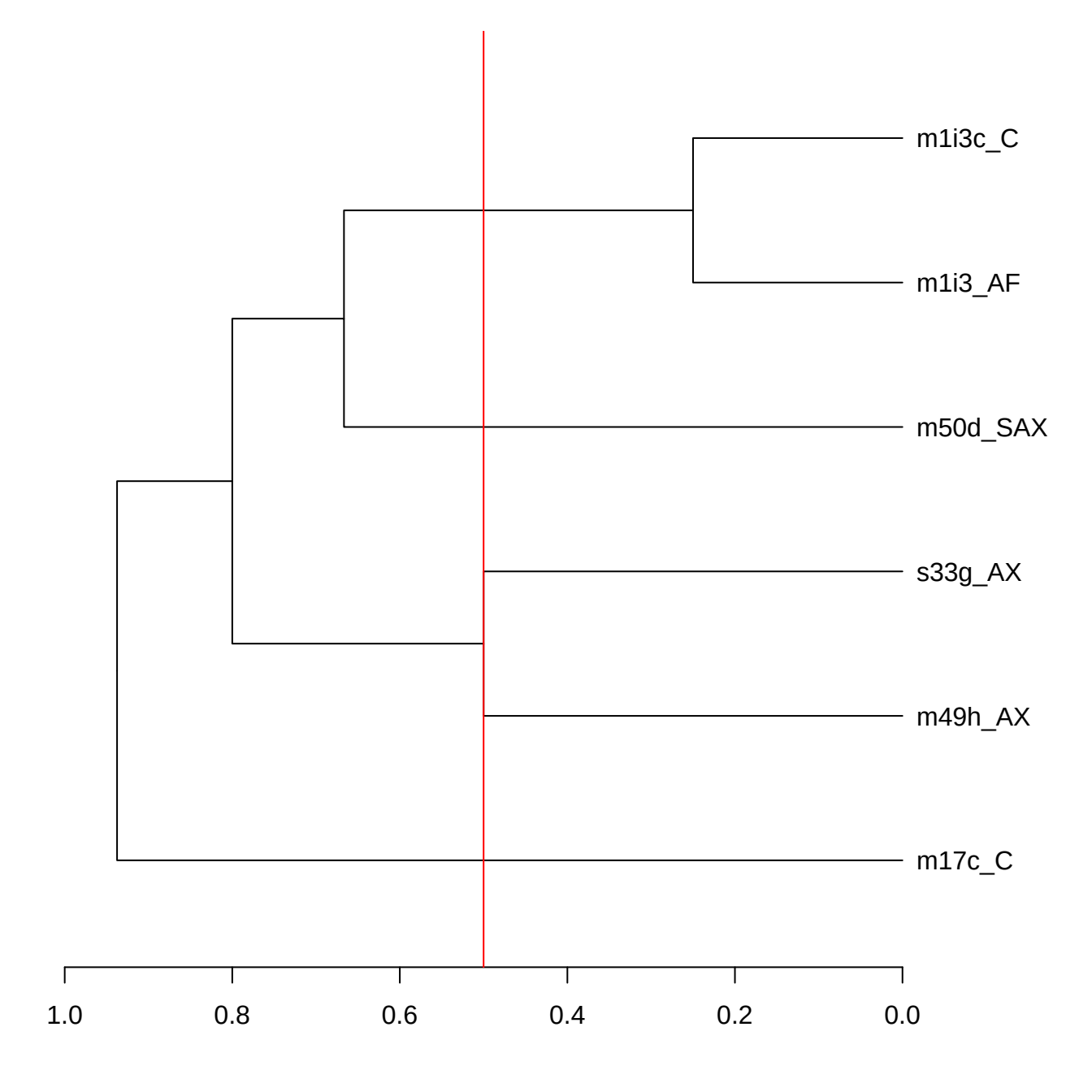
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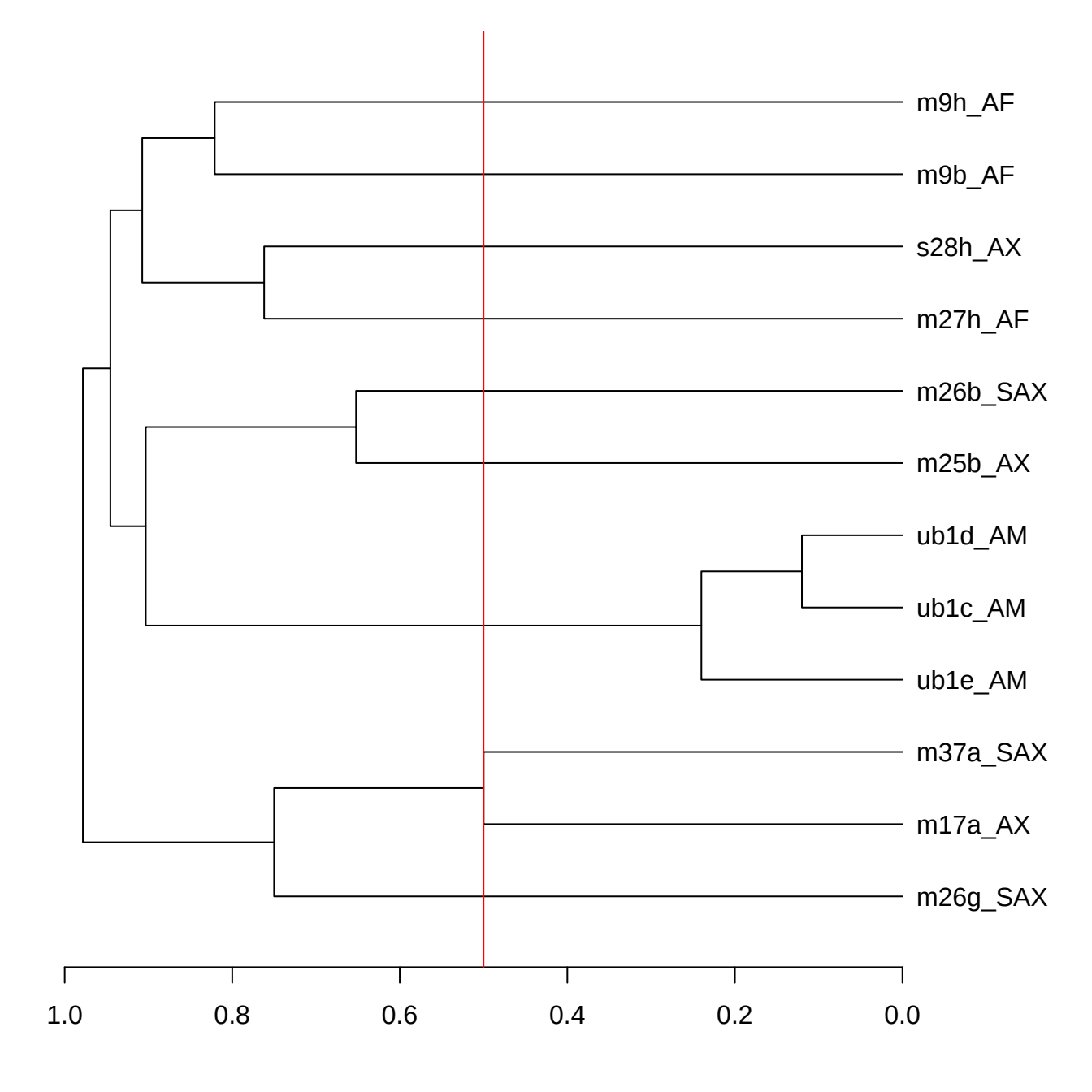
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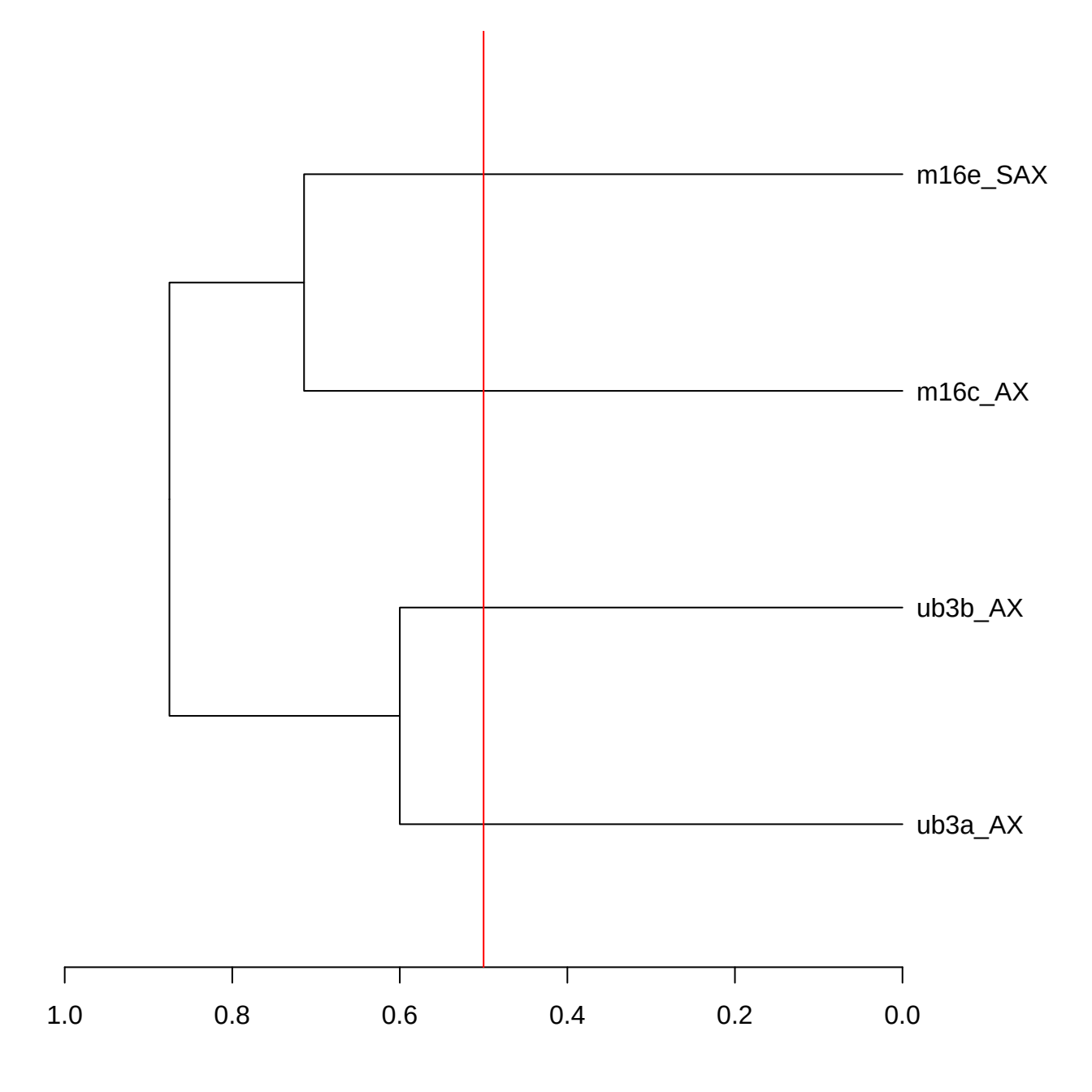
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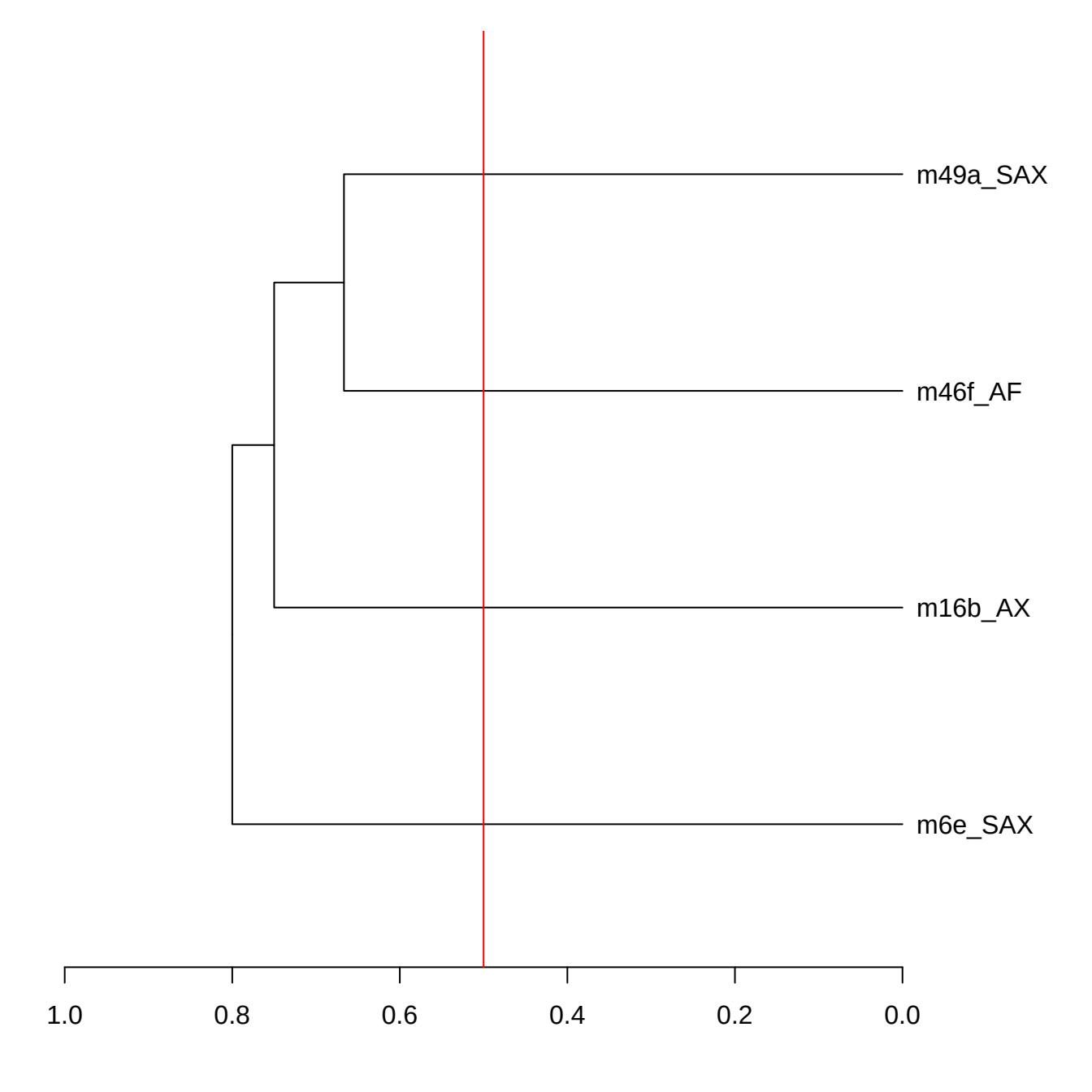
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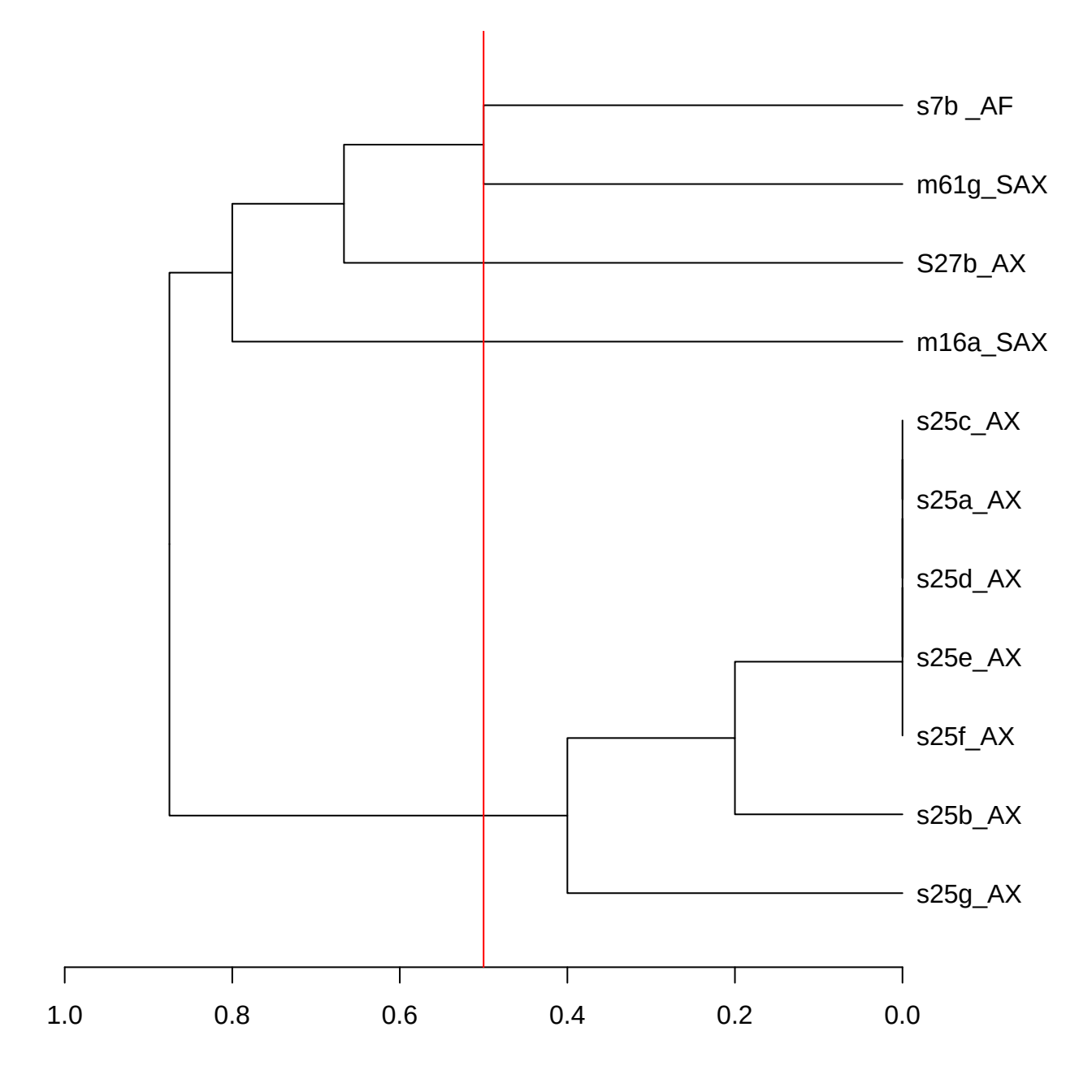
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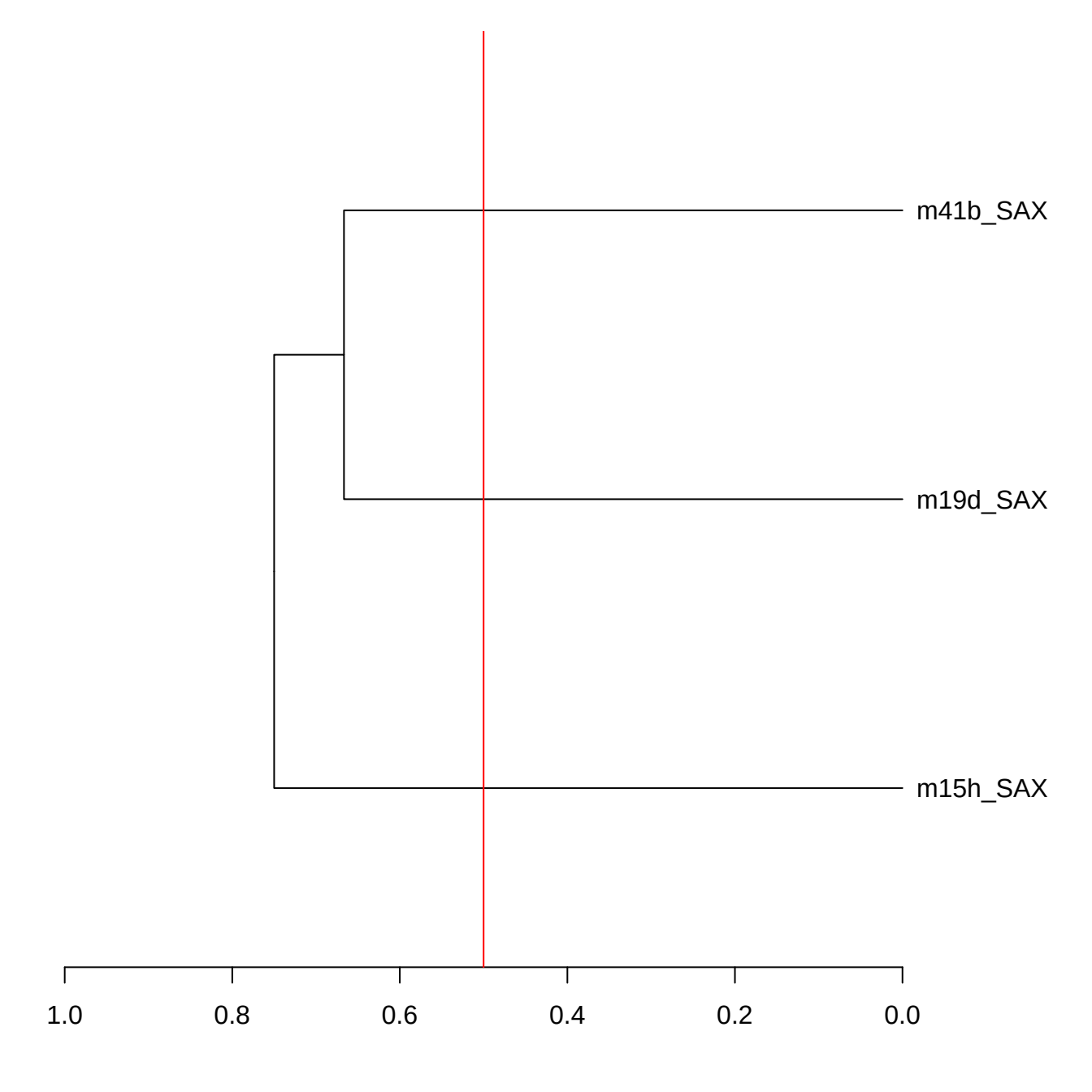
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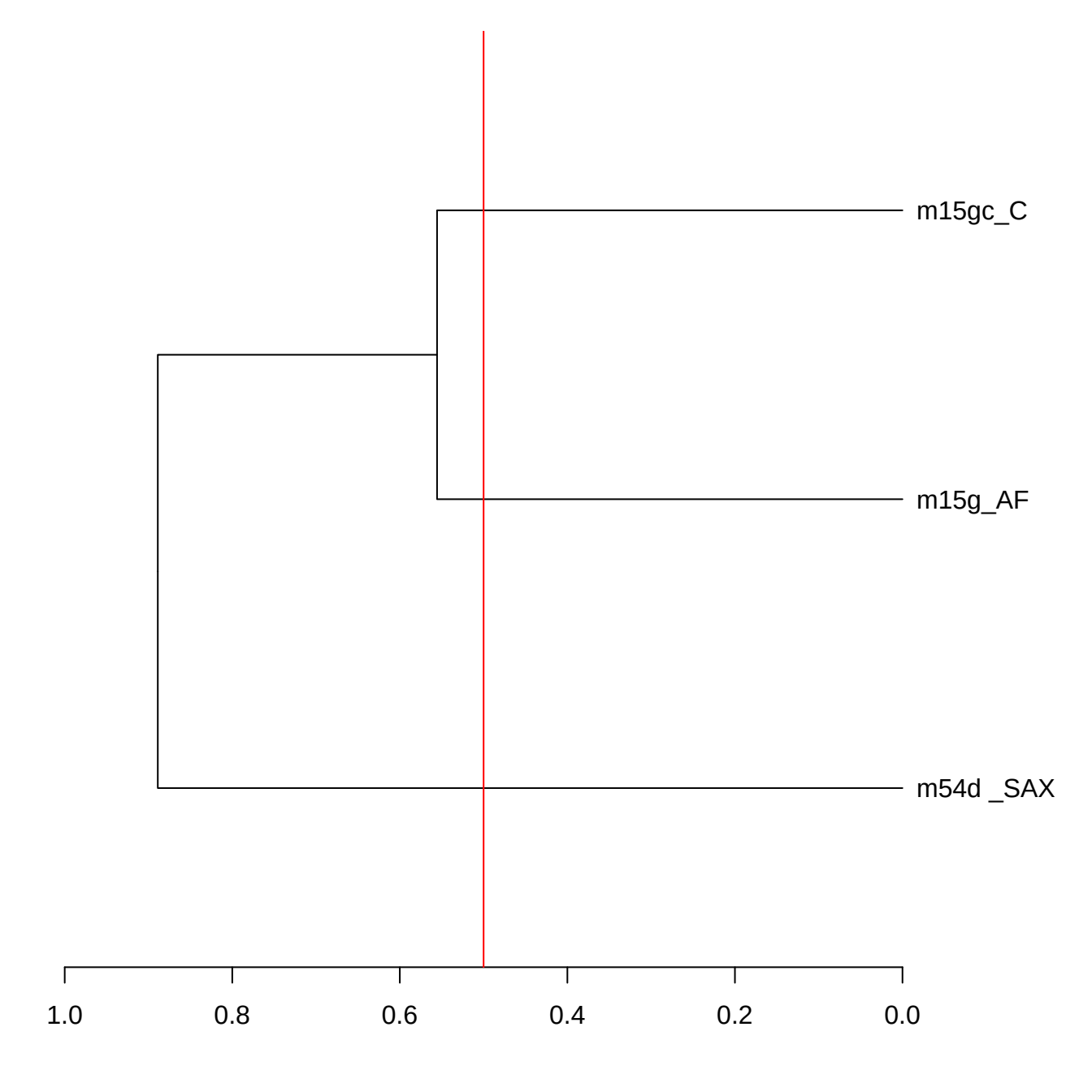
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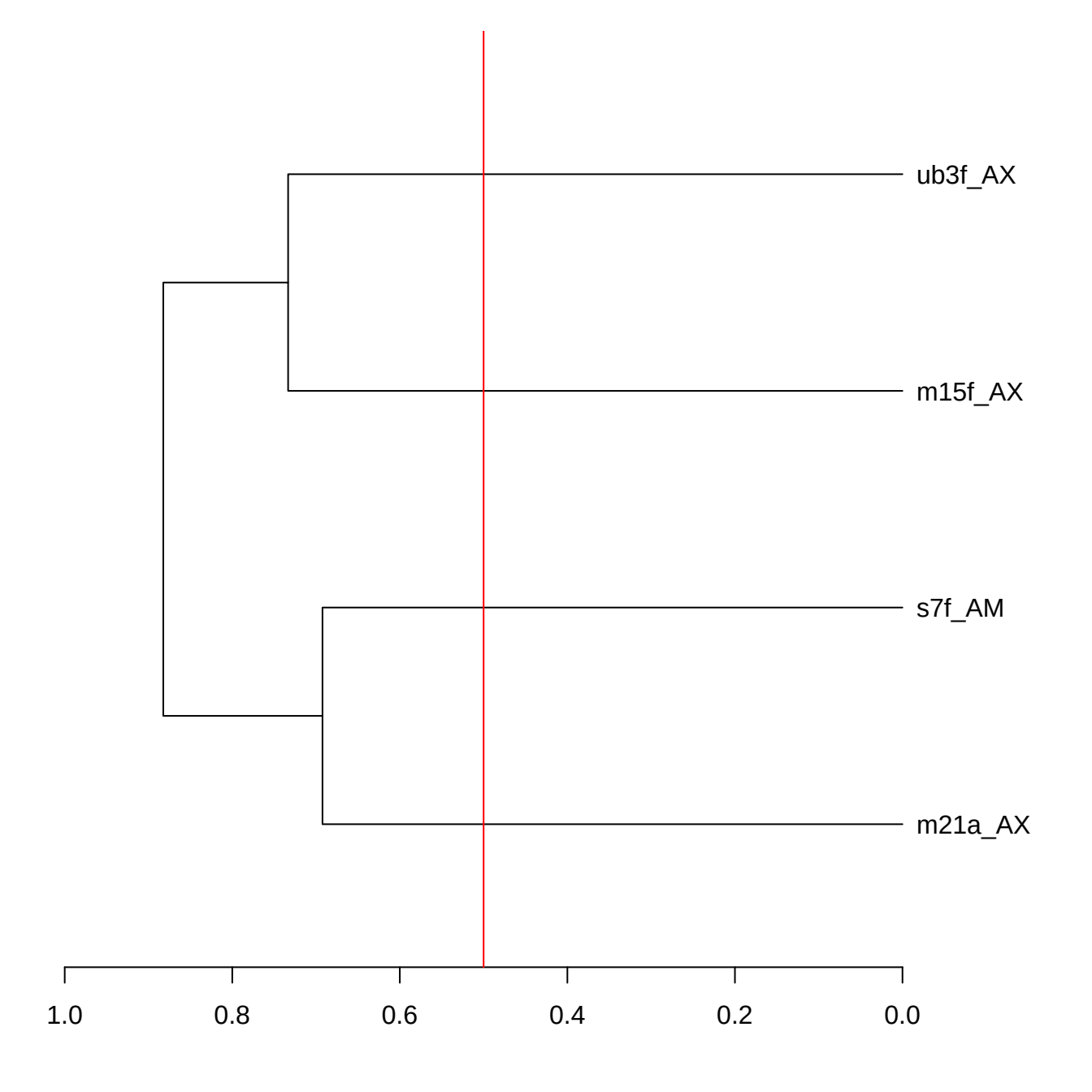
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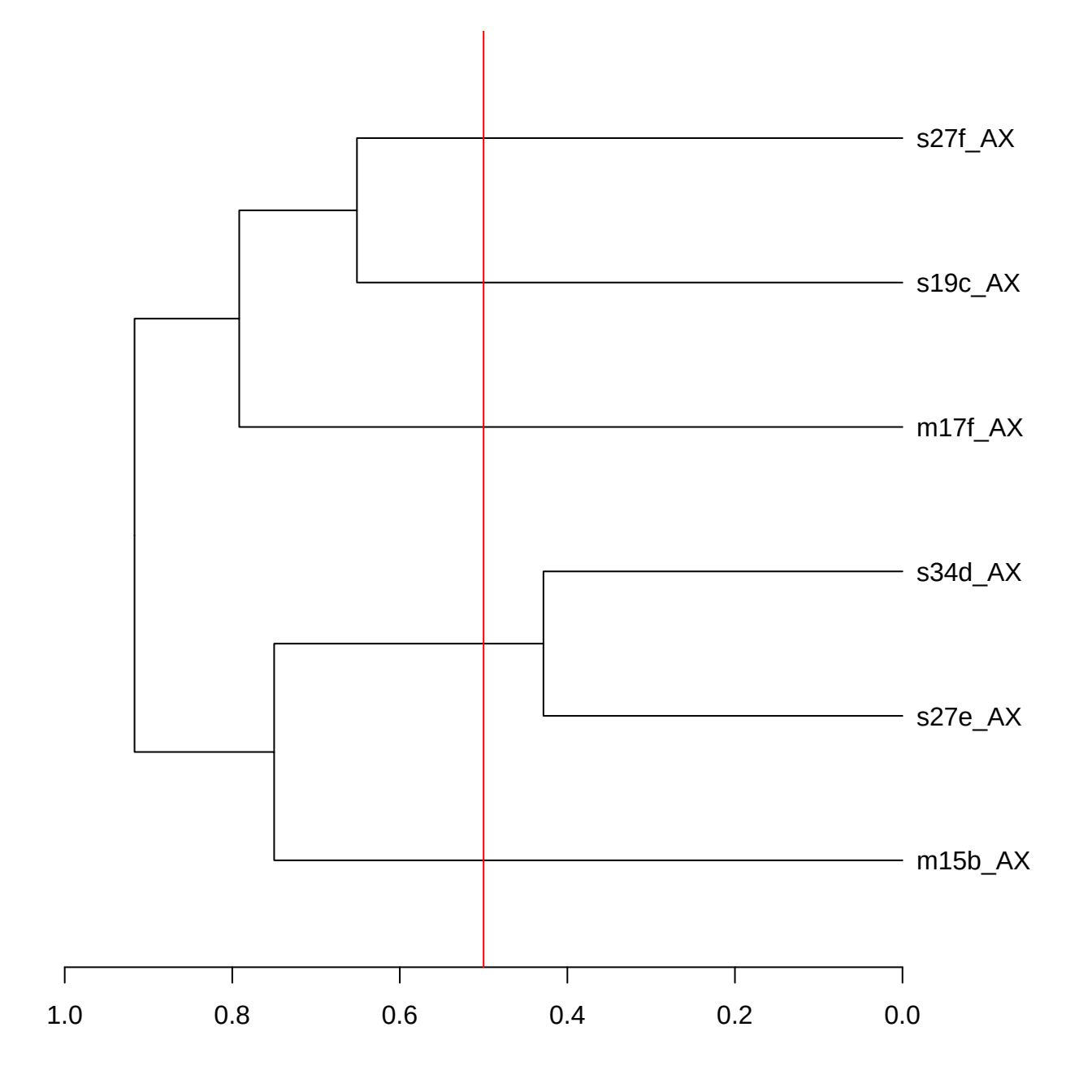
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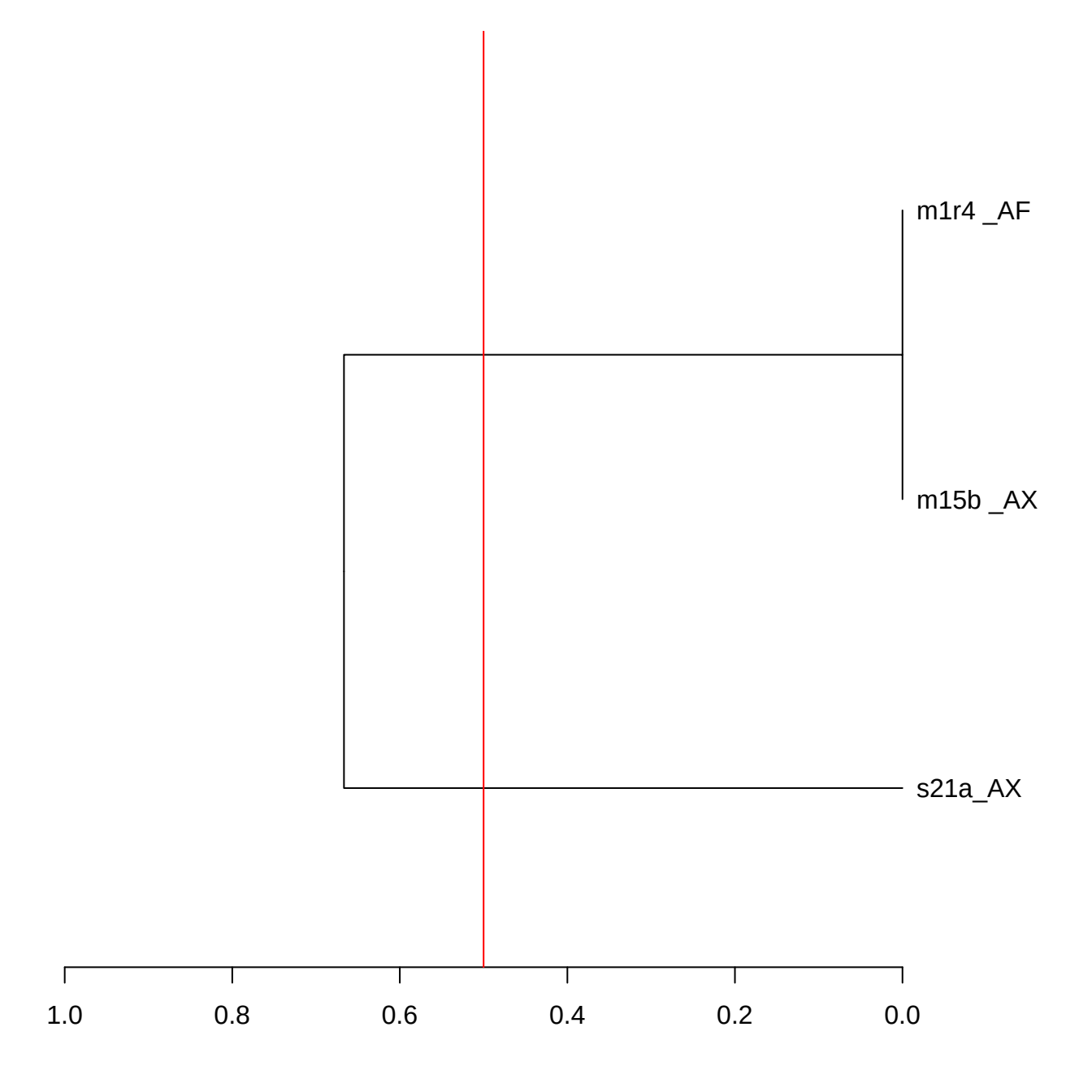
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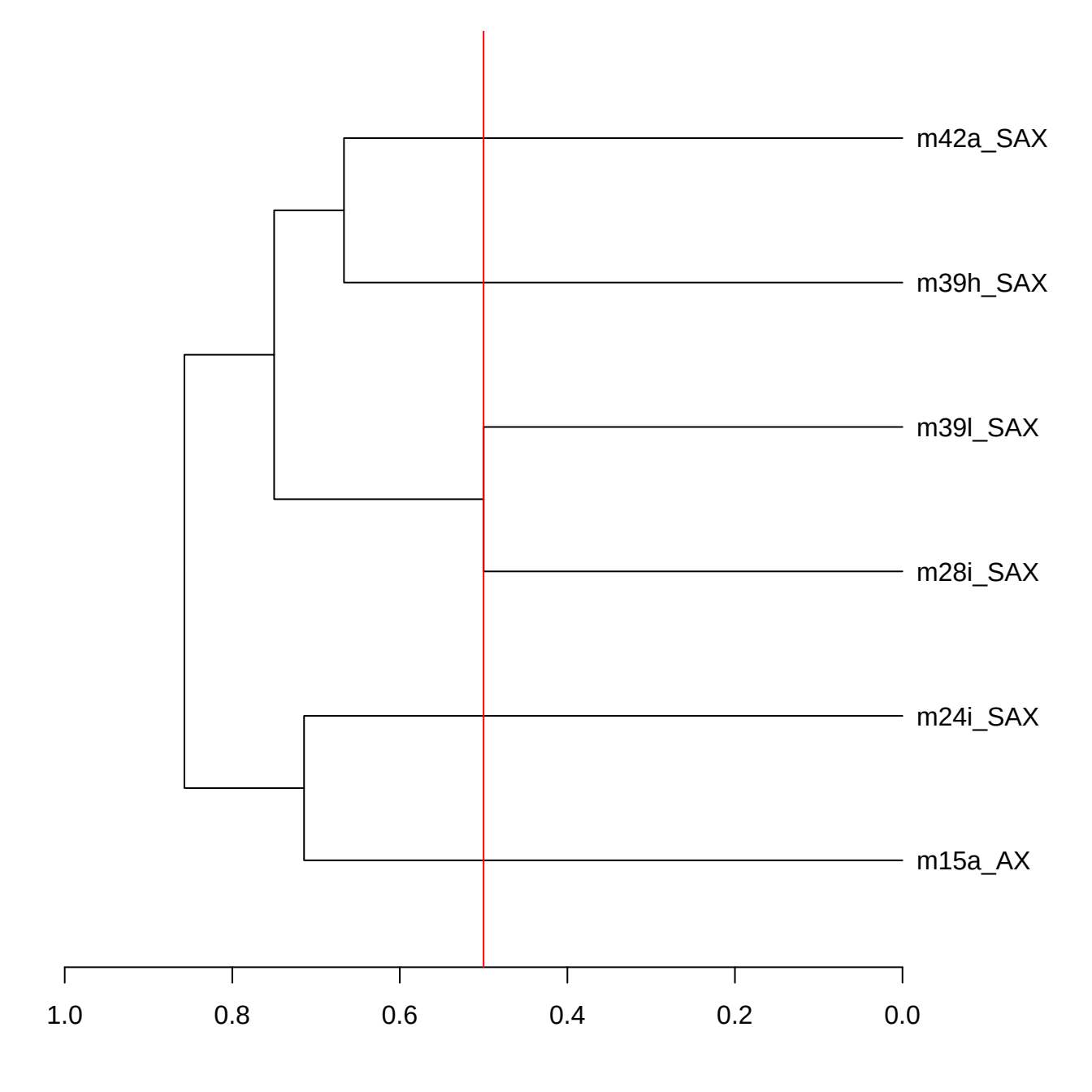
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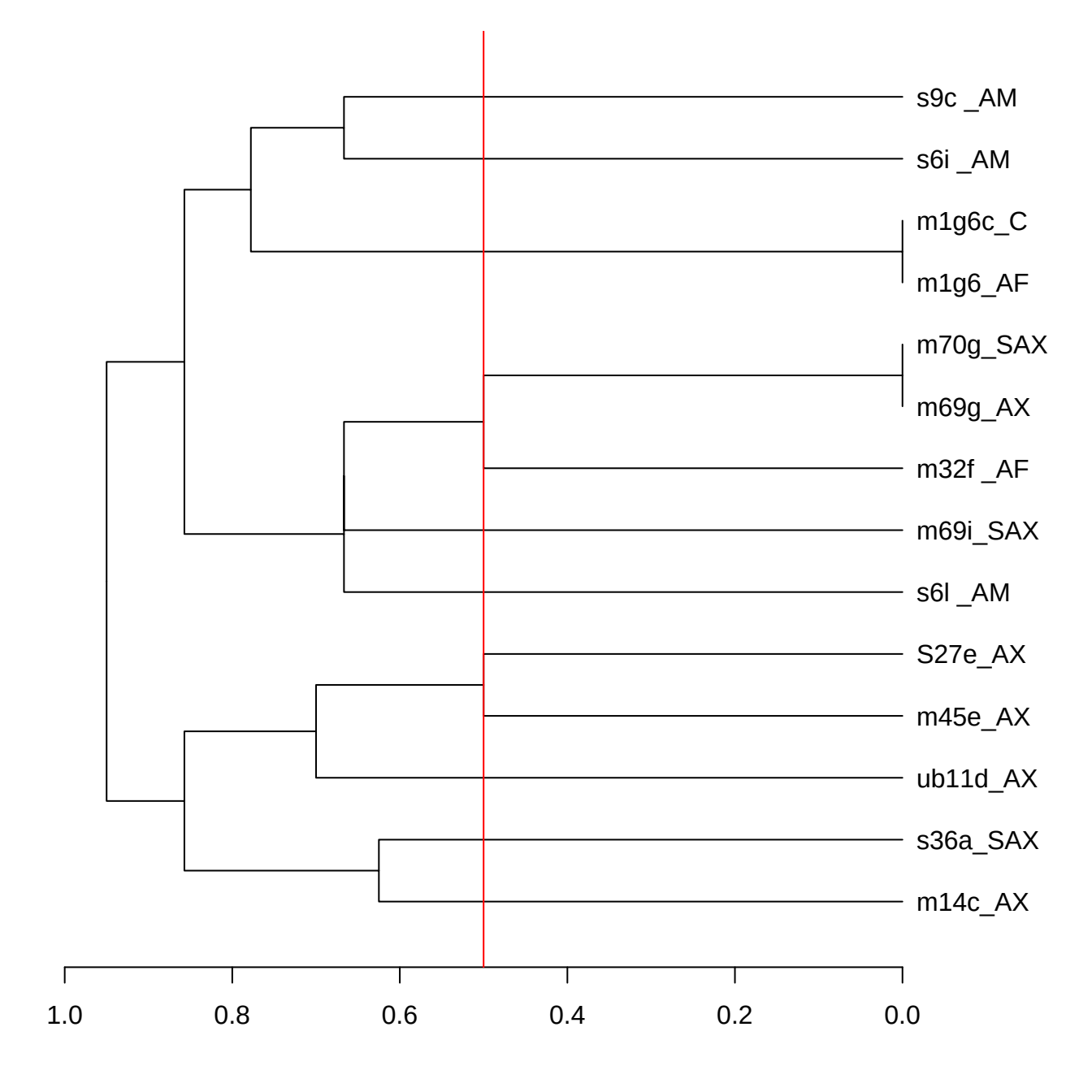
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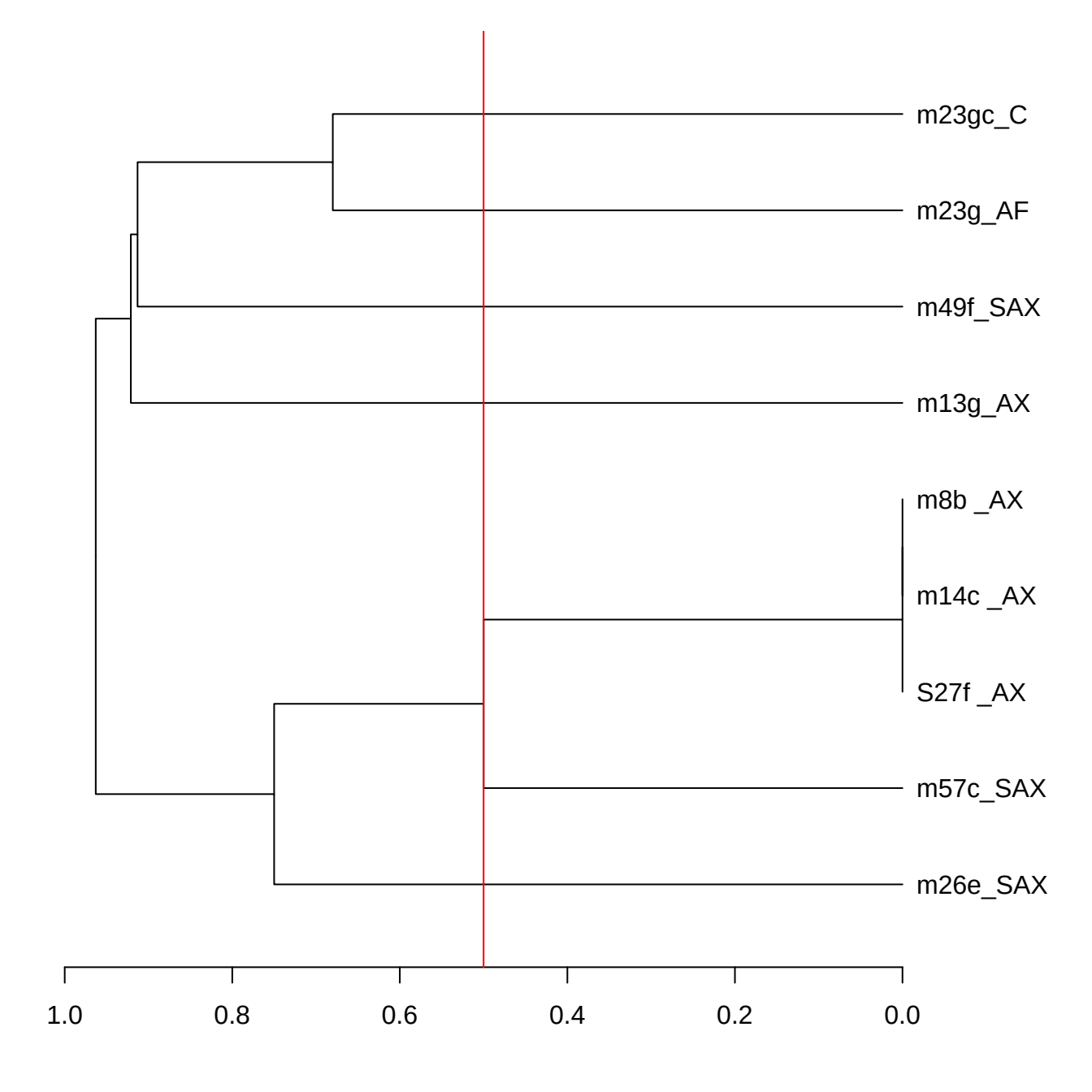
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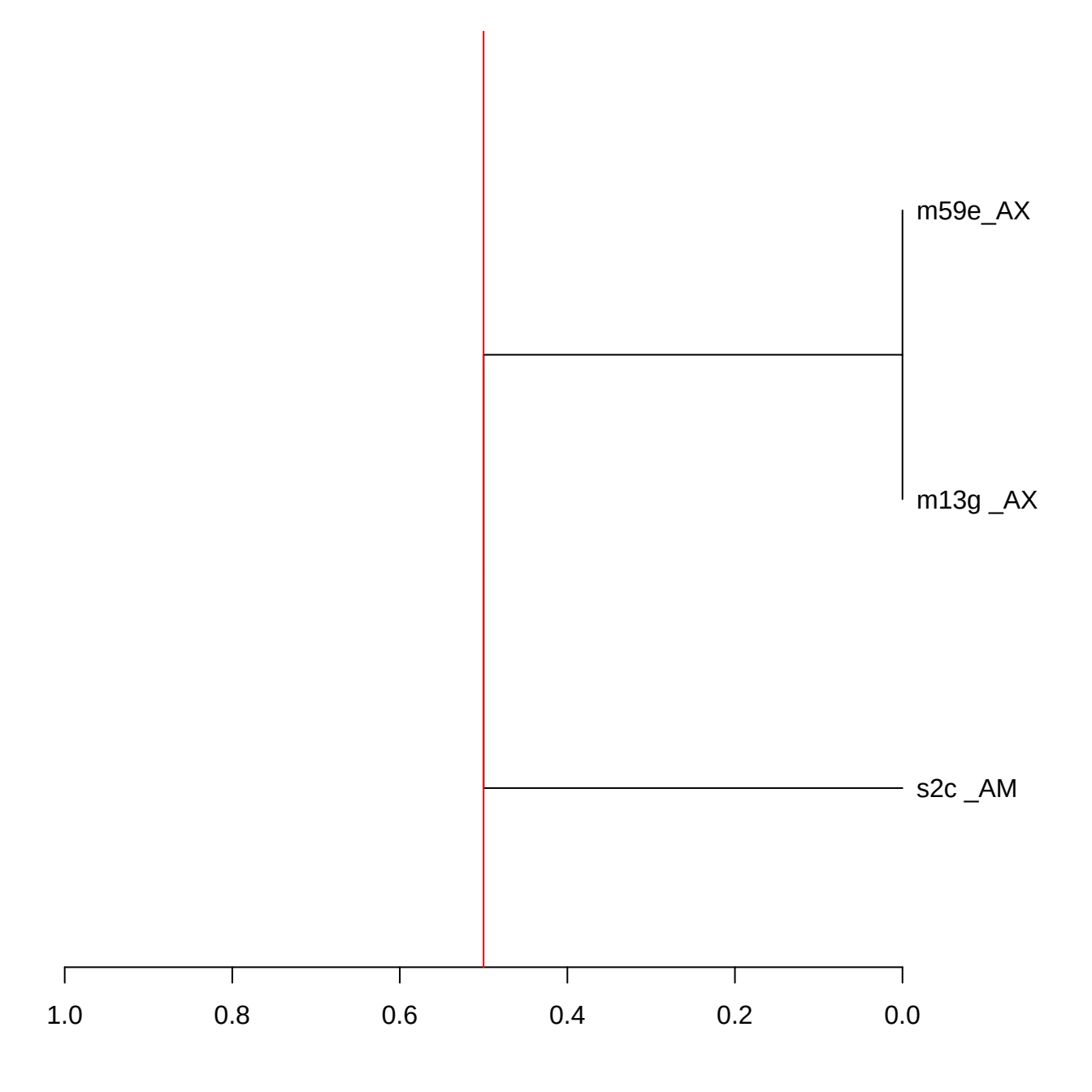
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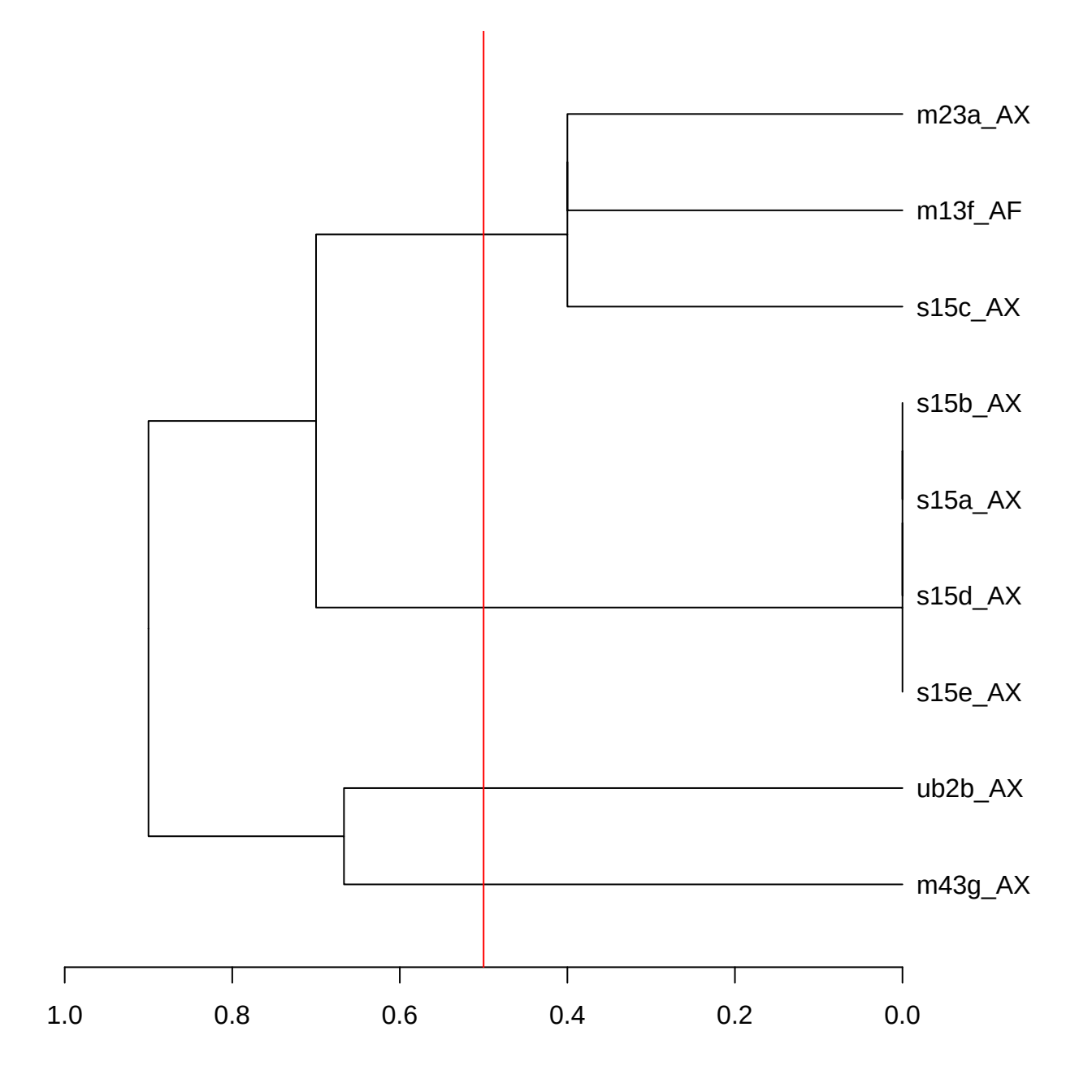
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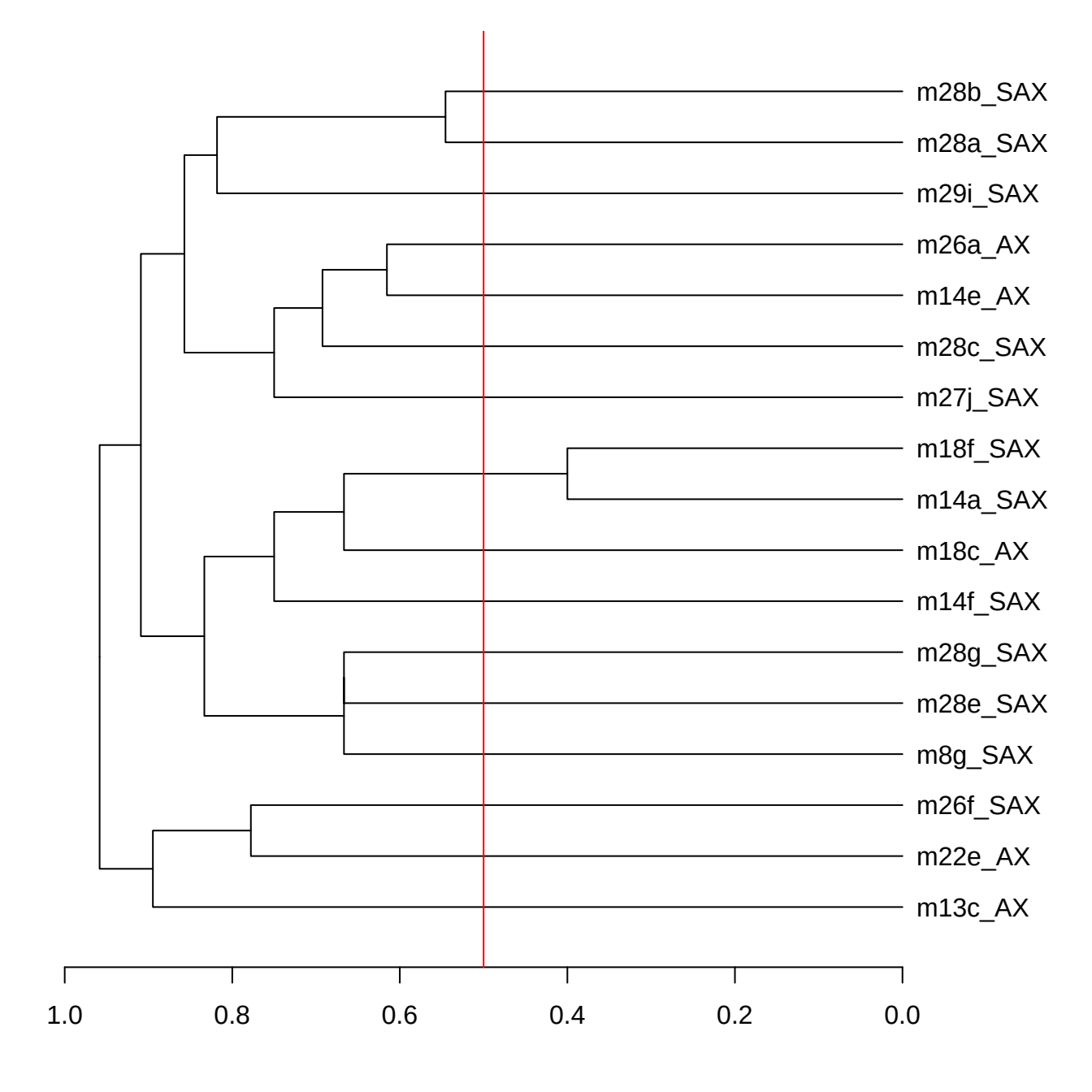
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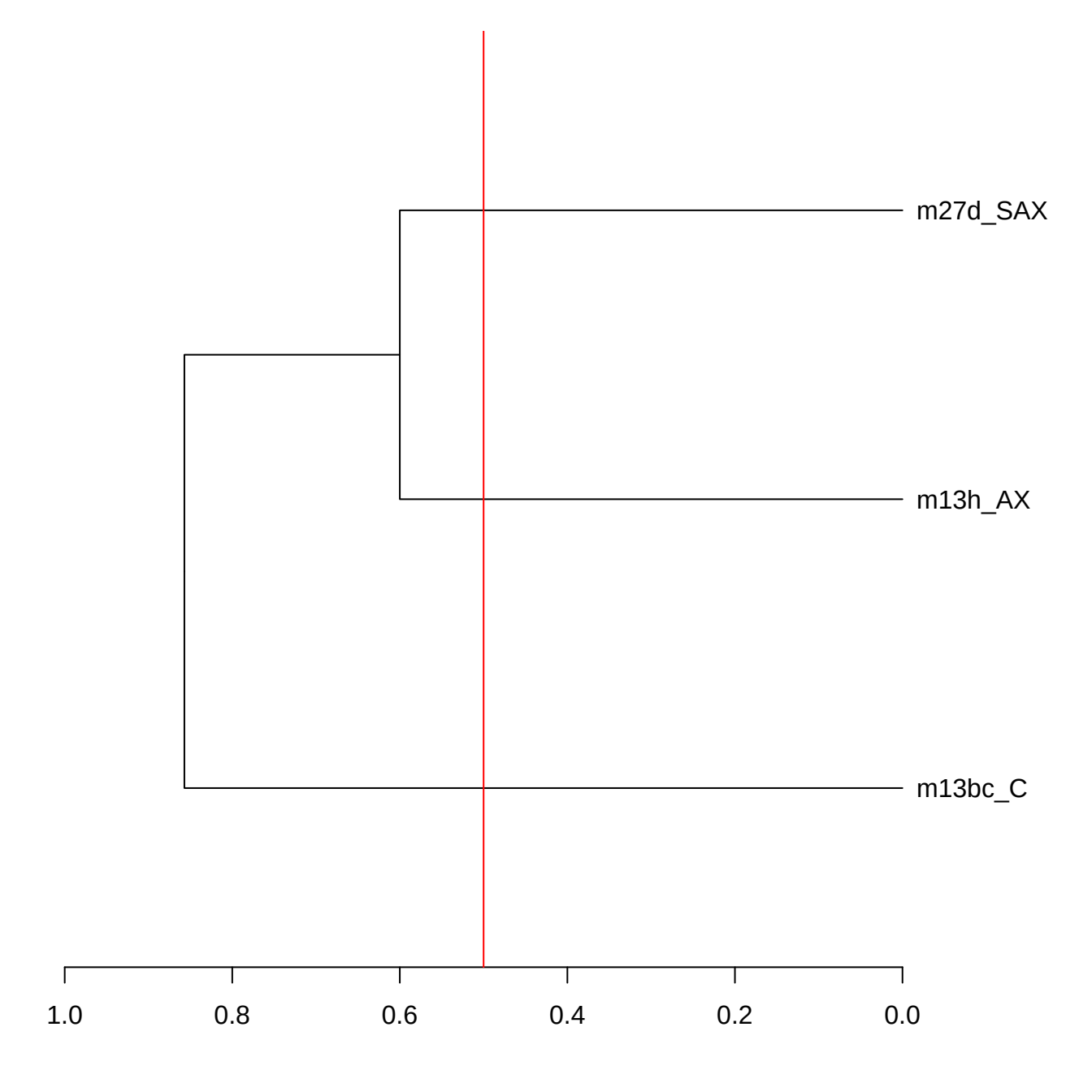
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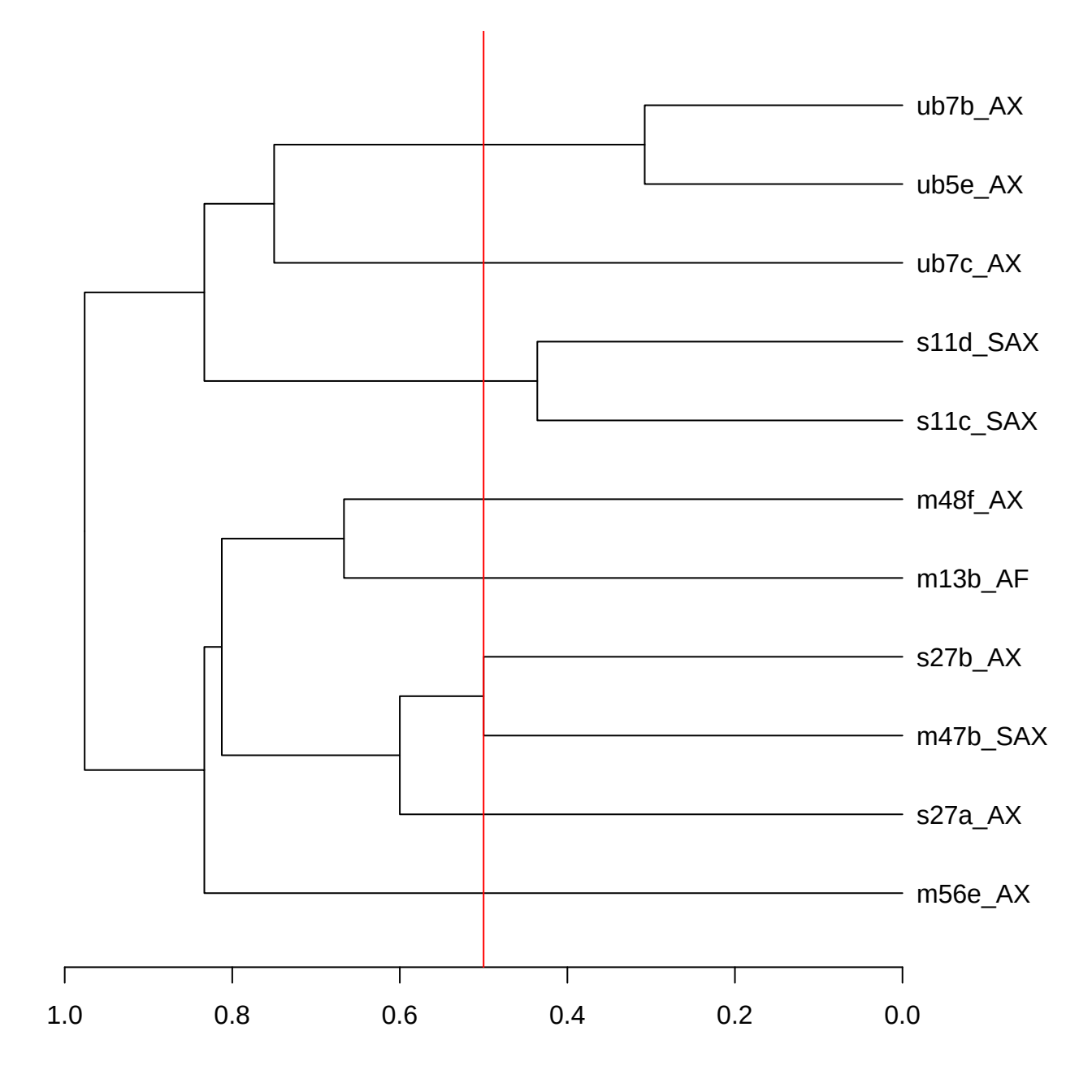
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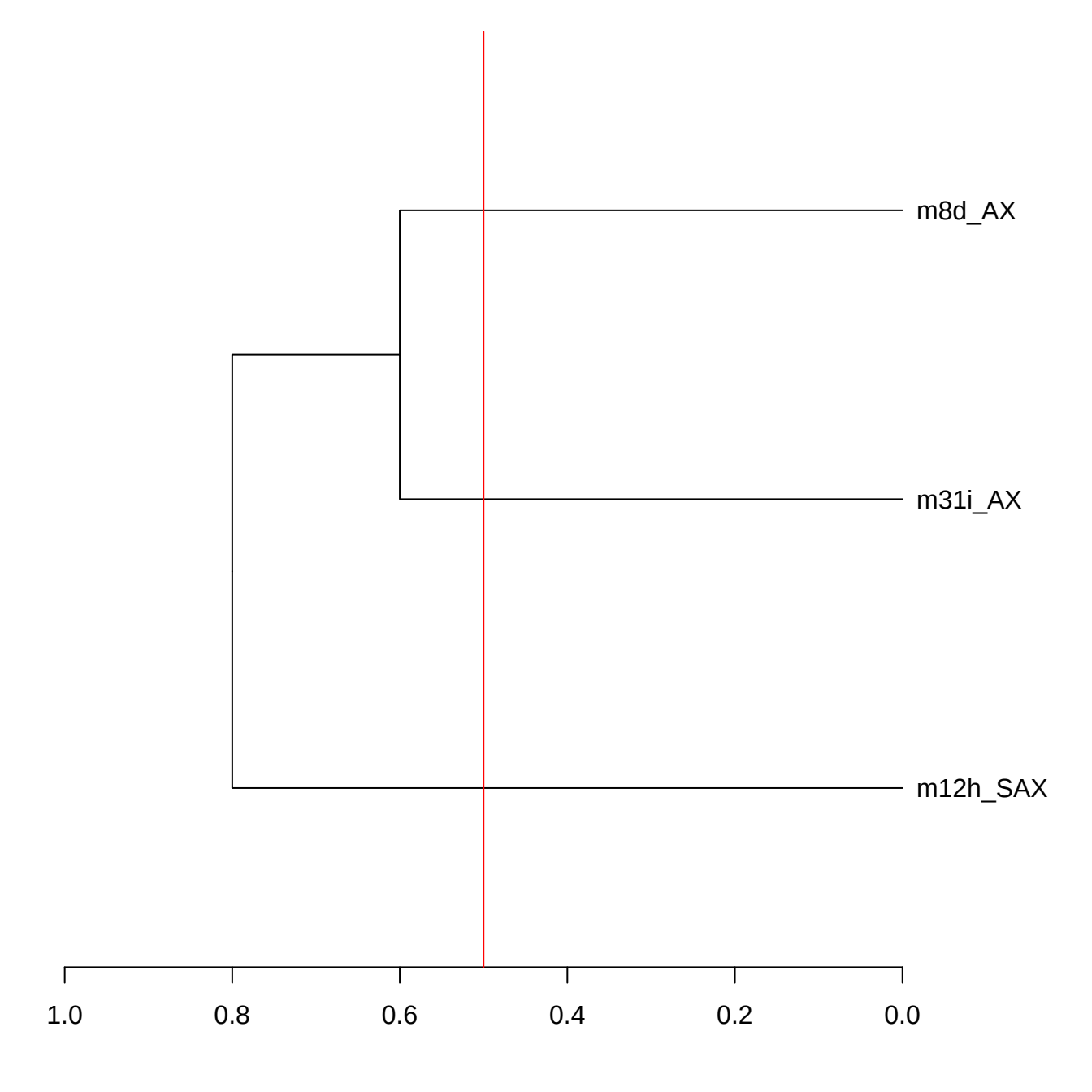
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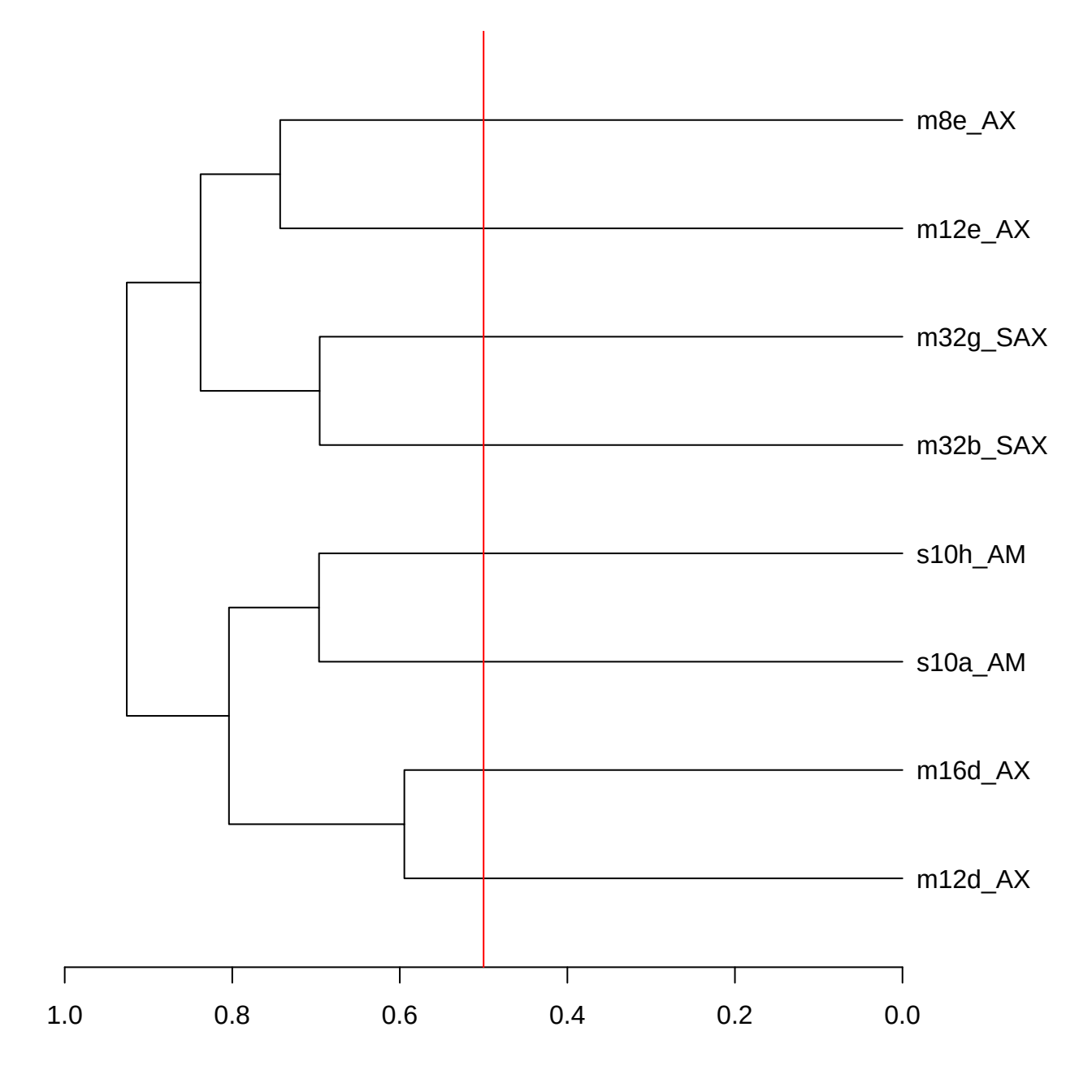
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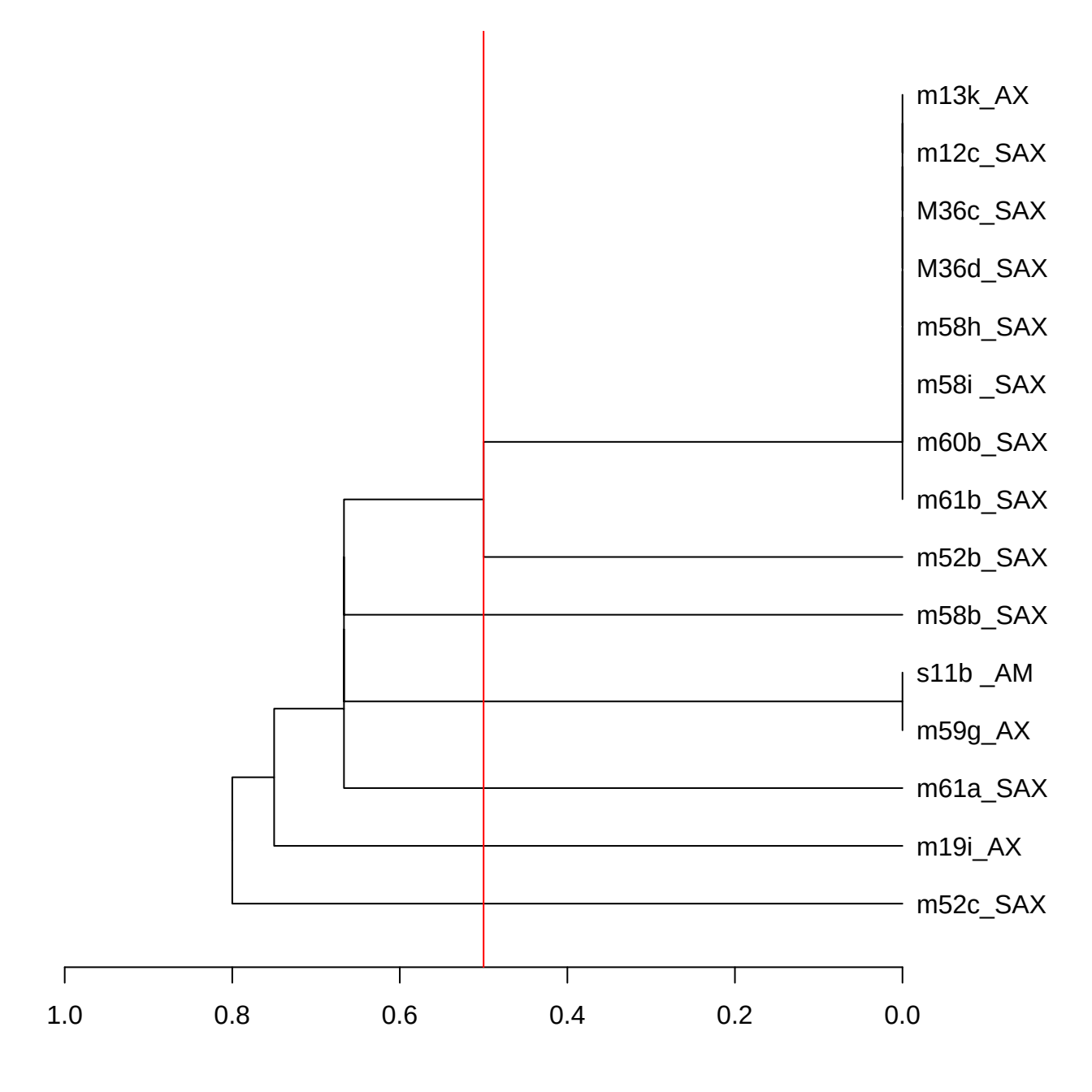
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m52b_SAX
m58b_SAX
s11b _AM
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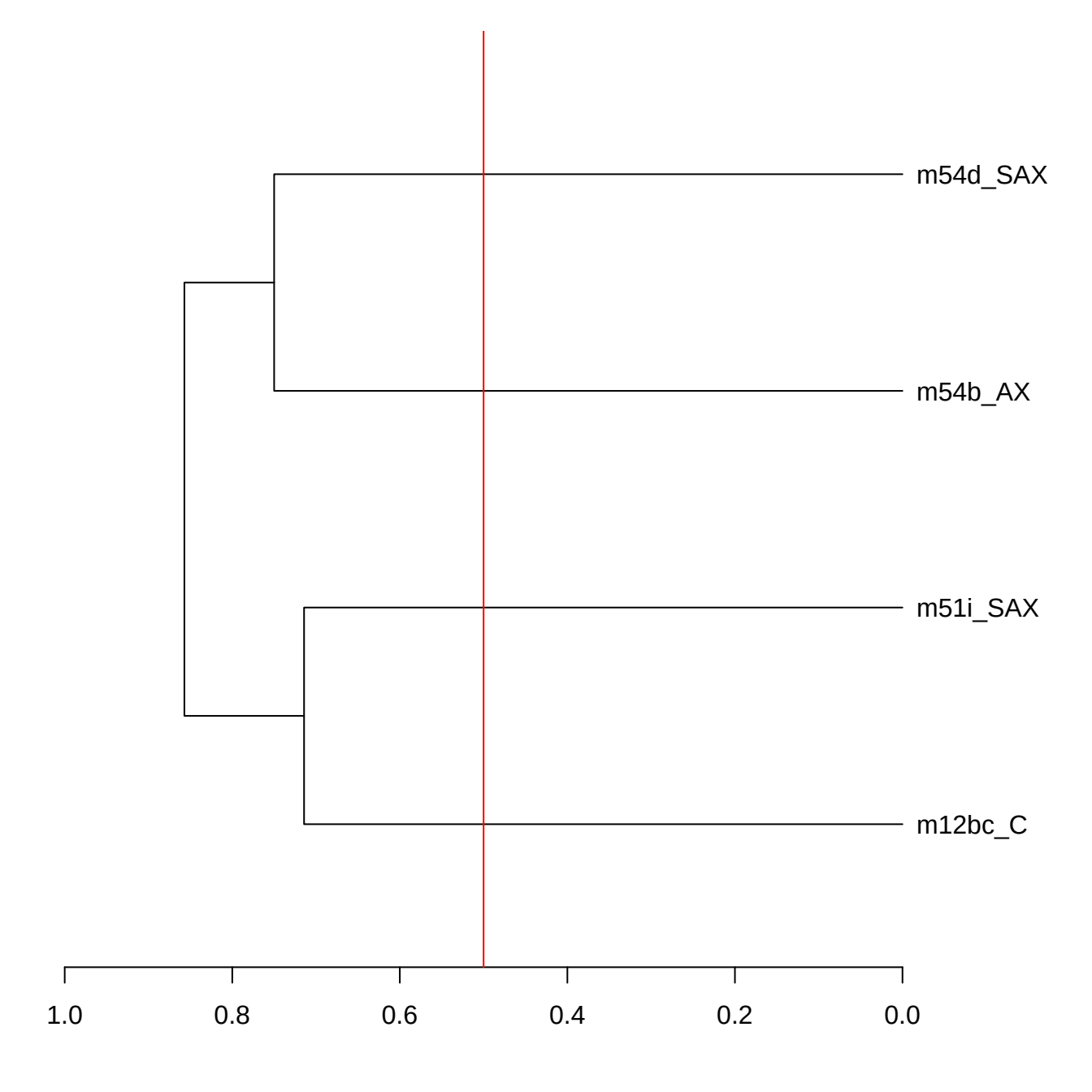
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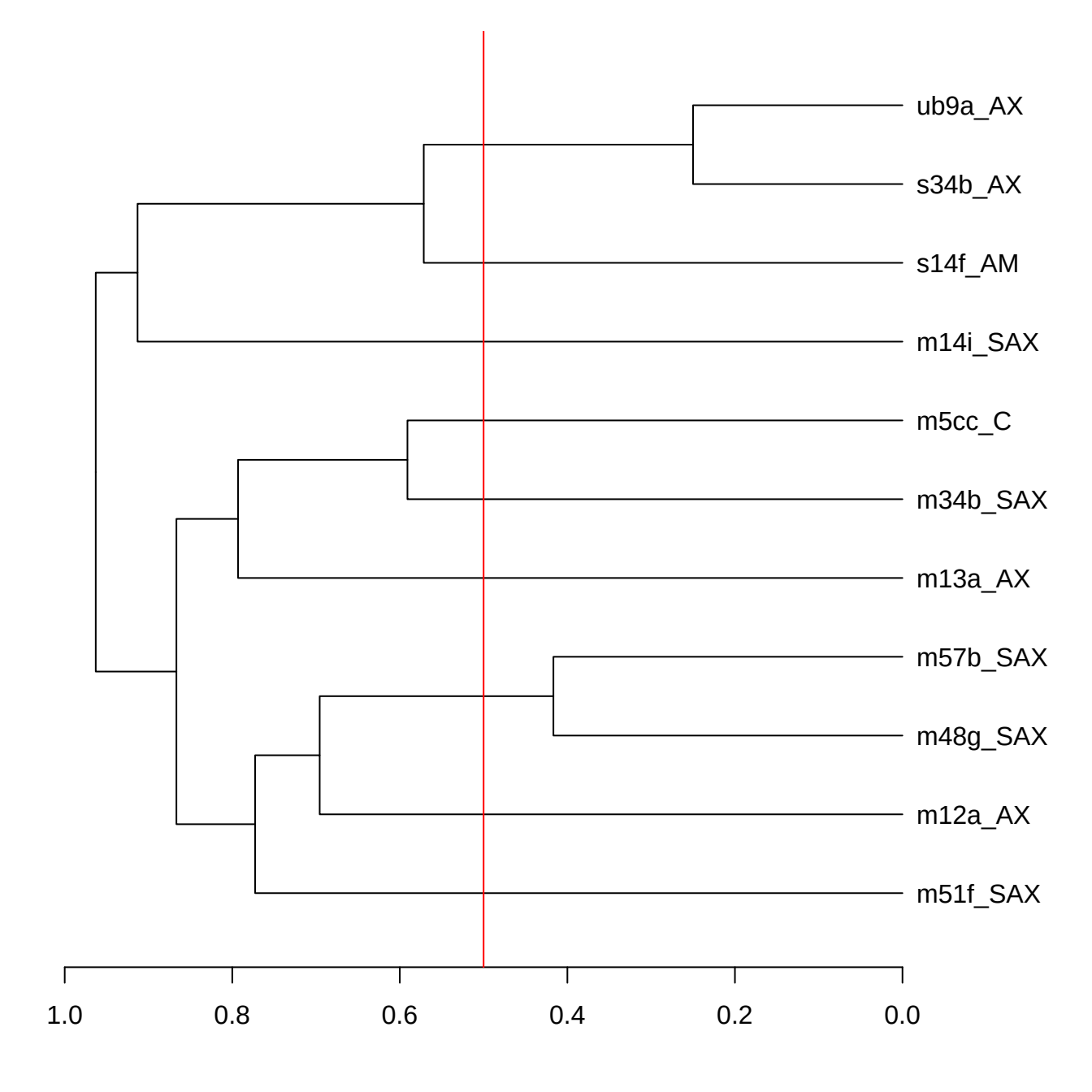
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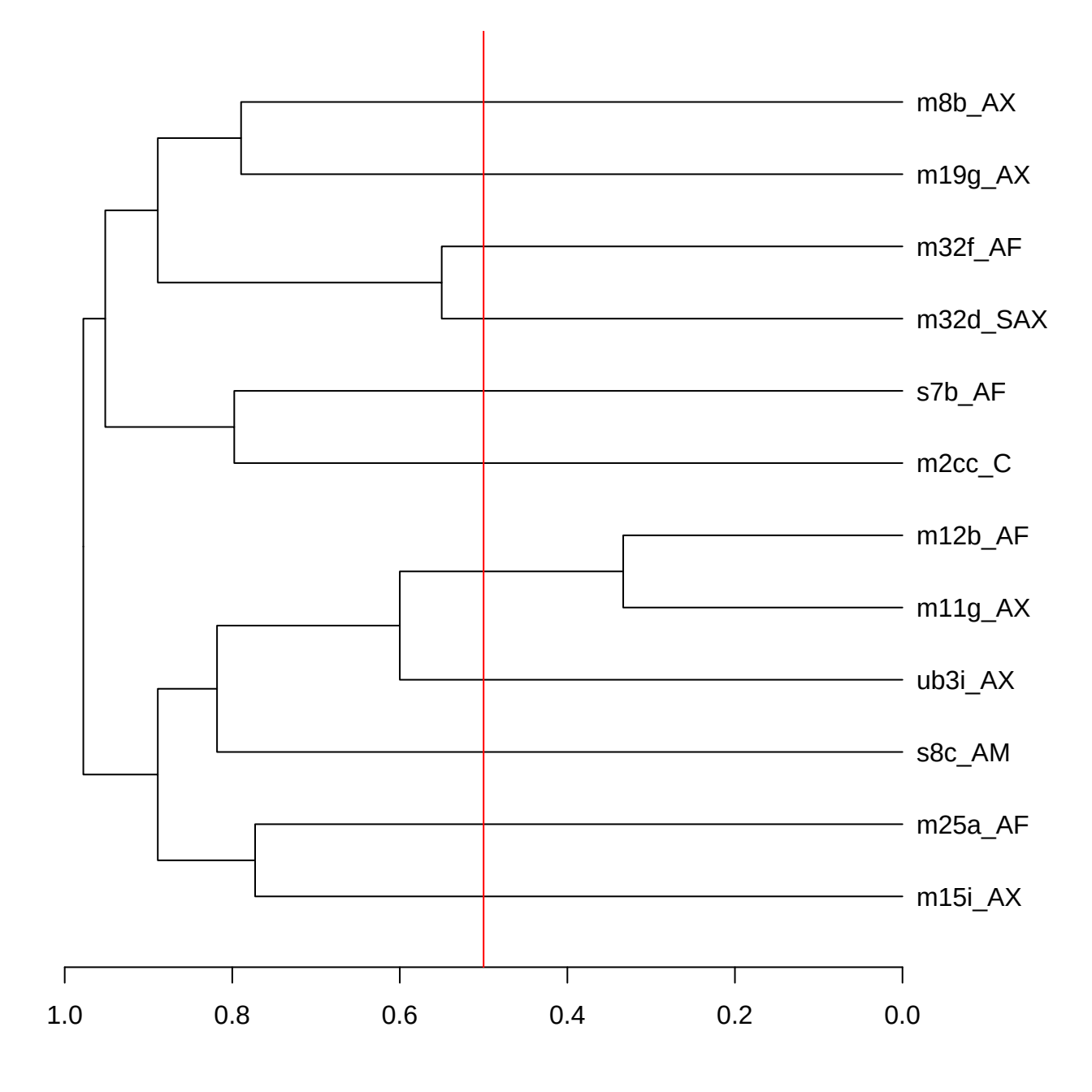
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m2cc_C
m12b_AF
m11g_AX
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m25a_AF
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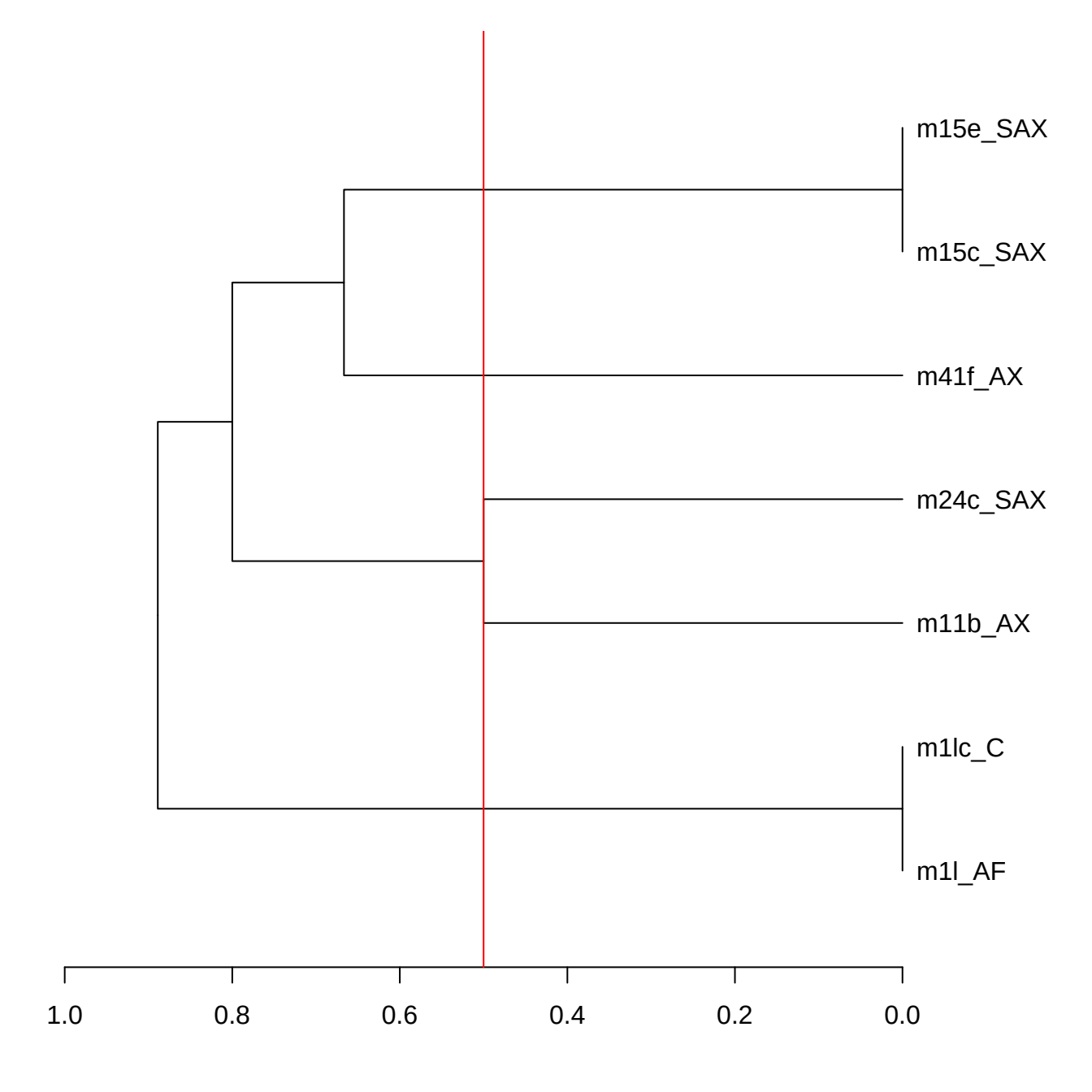
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m1l_AF
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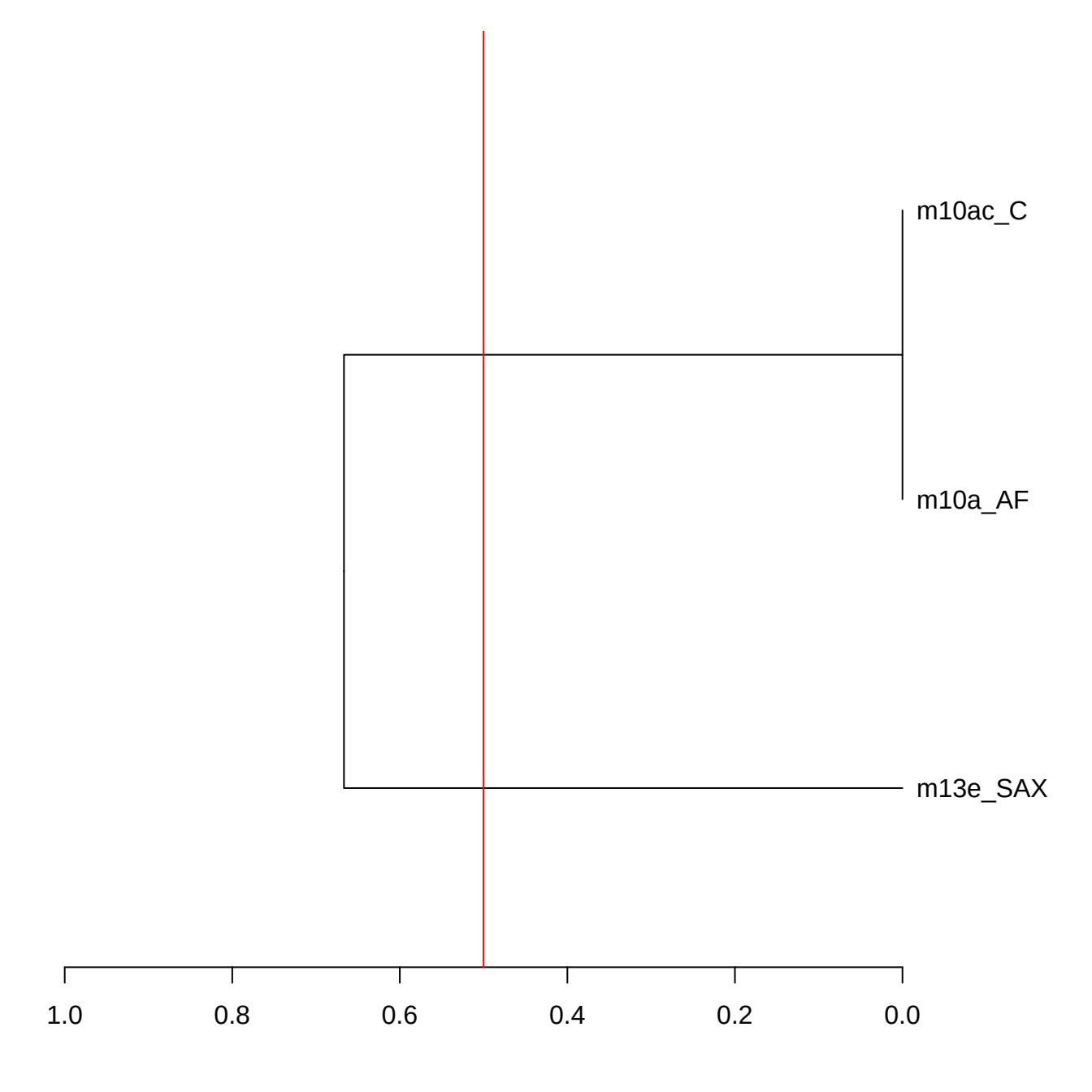
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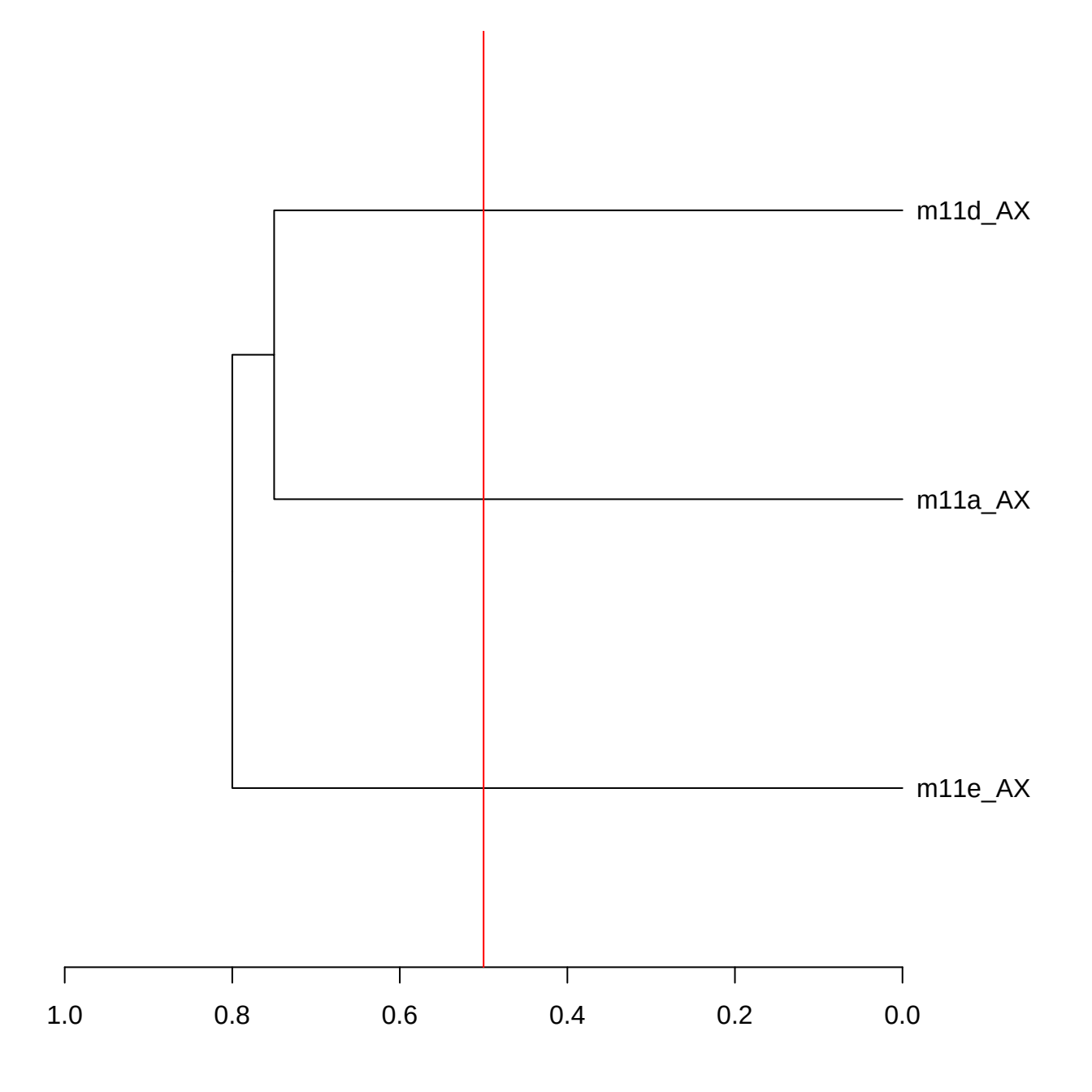
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m11a_AX
m11e_AX
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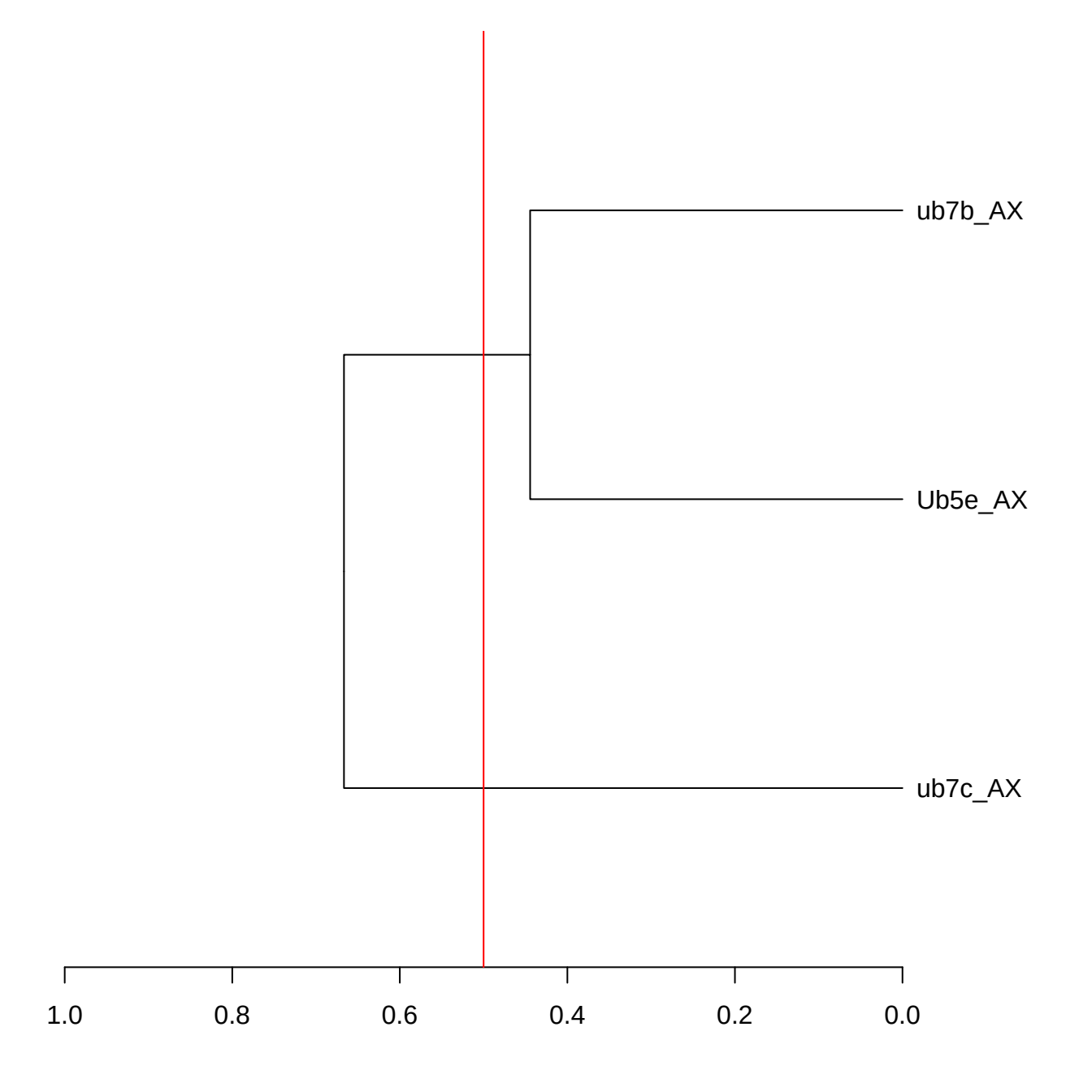
0.6
0.4
0.2
0.0

Appendix IV

Dendrogram for all individuals sighted ≥ 10 times

Complete Linkage Method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ub7c_AX
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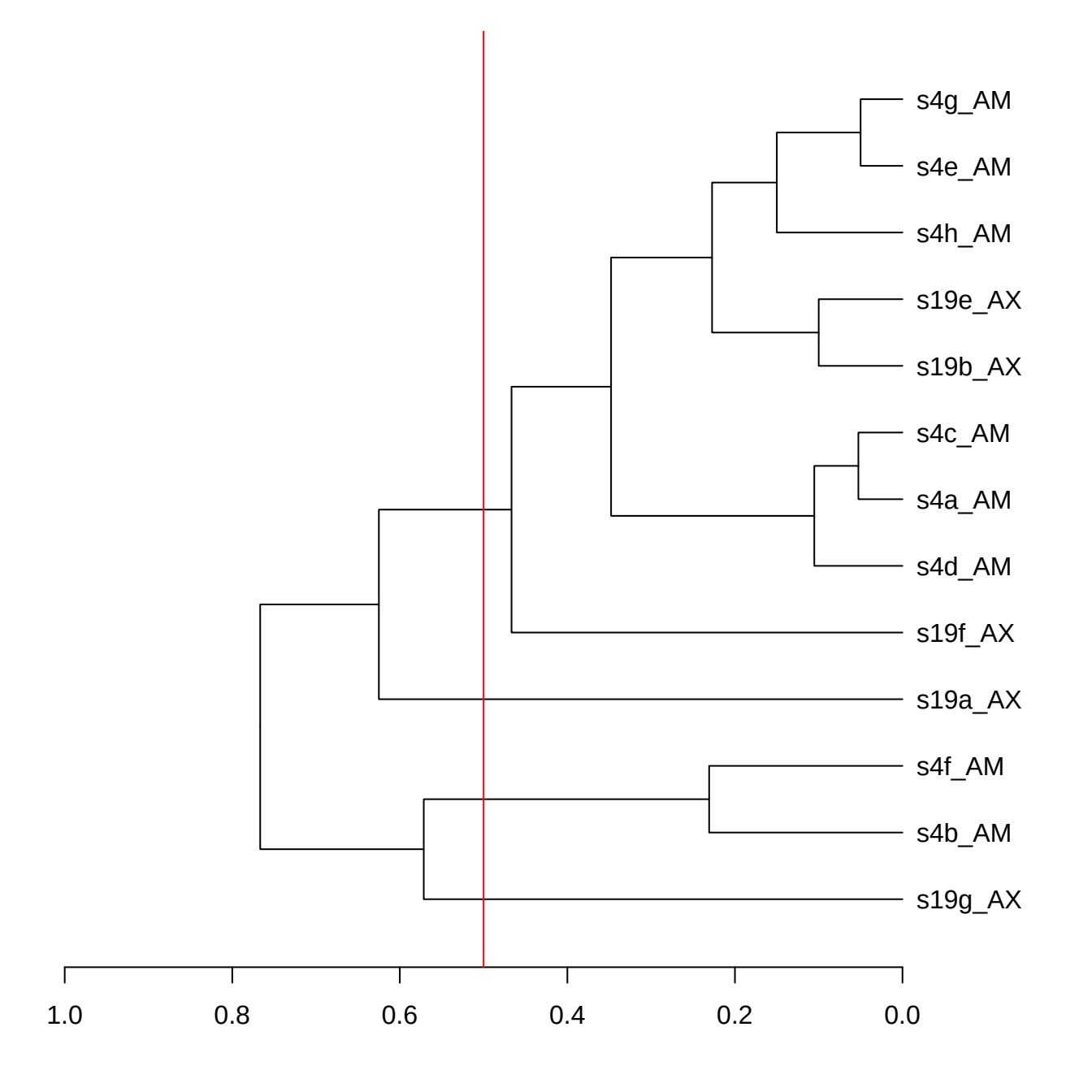
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s4e_AM
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s19e_AX
s19b_AX
s4c_AM
s4a_AM
s4d_AM
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s19g_AX
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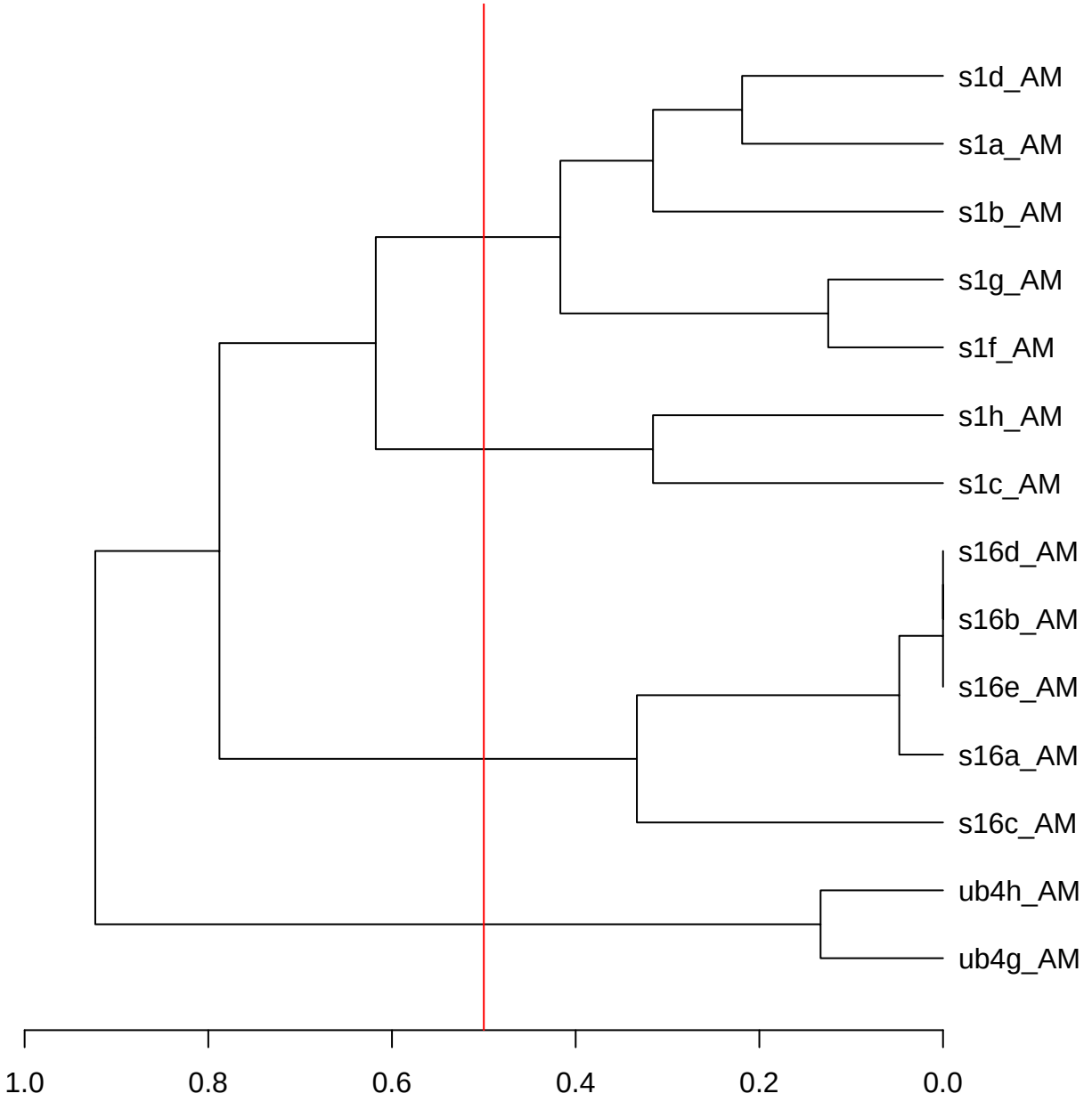
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s1c_AM
s16d_AM
s16b_AM
s16e_AM
s16a_AM
s16c_AM
ub4h_AM
ub4g_AM
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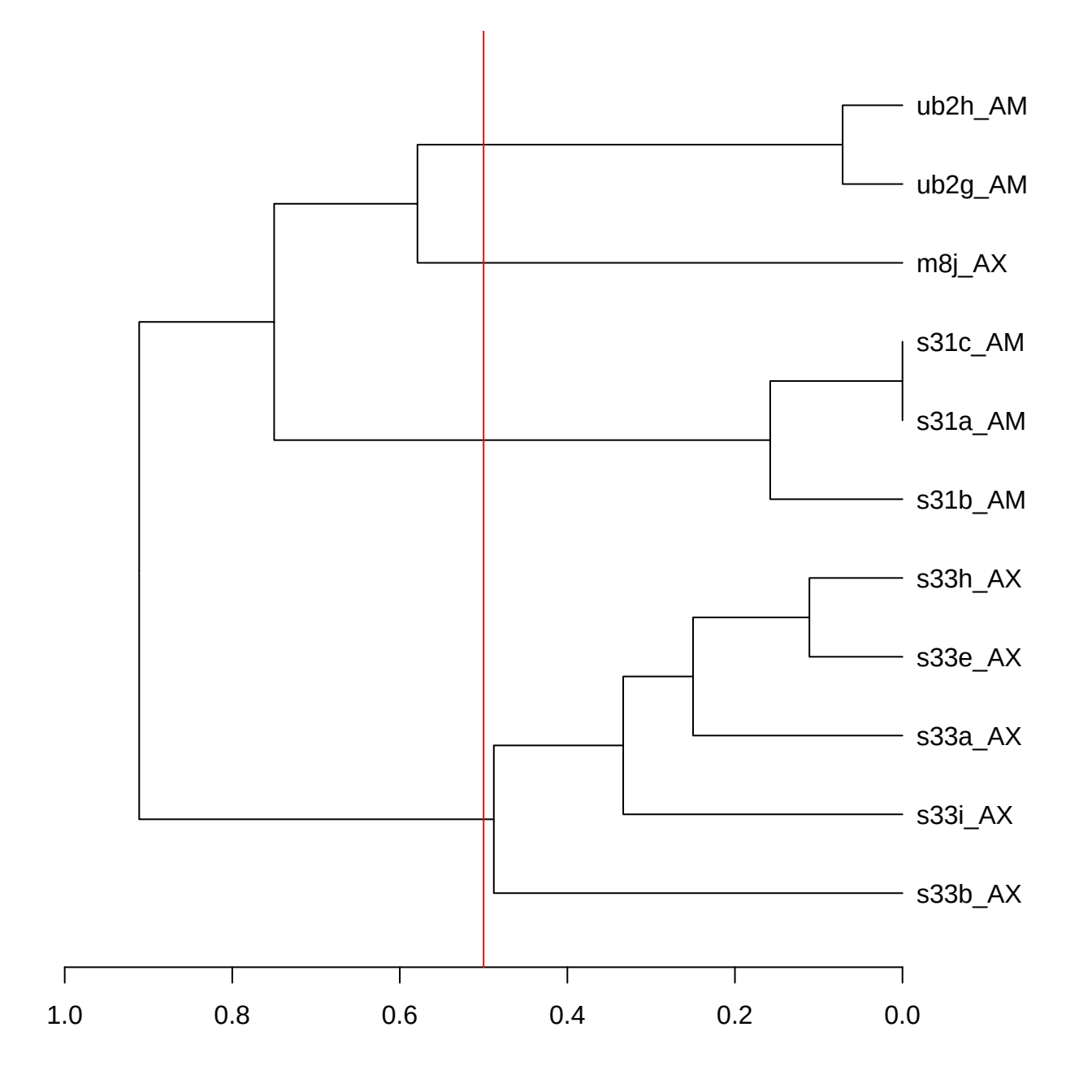
0.8
0.6
0.4
0.2
0.0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s31b_AM
s33h_AX
s33e_AX
s33a_AX
s33i_AX
s33b_AX
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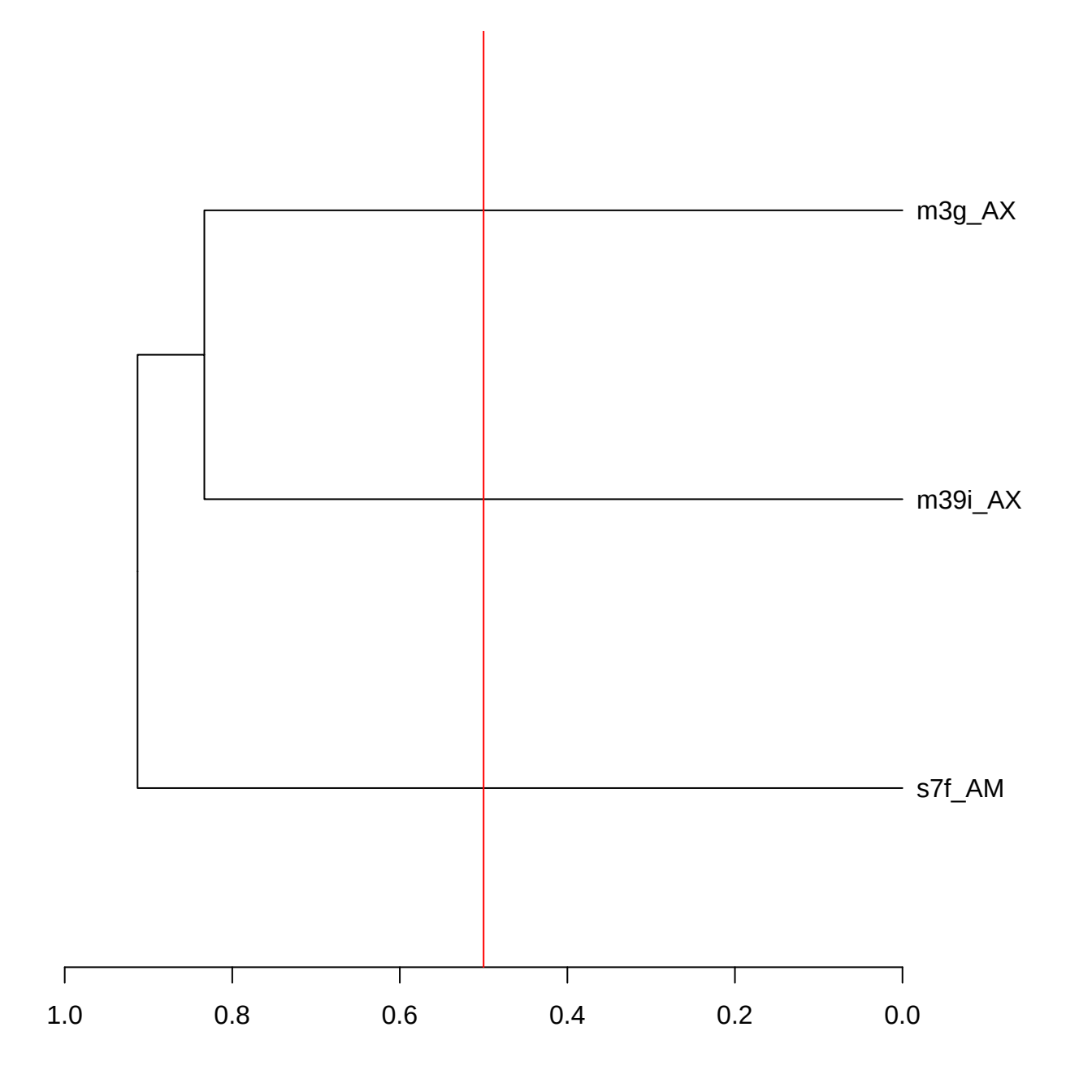
0.6
0.4
0.2
0.0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m39i_AX
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0.6
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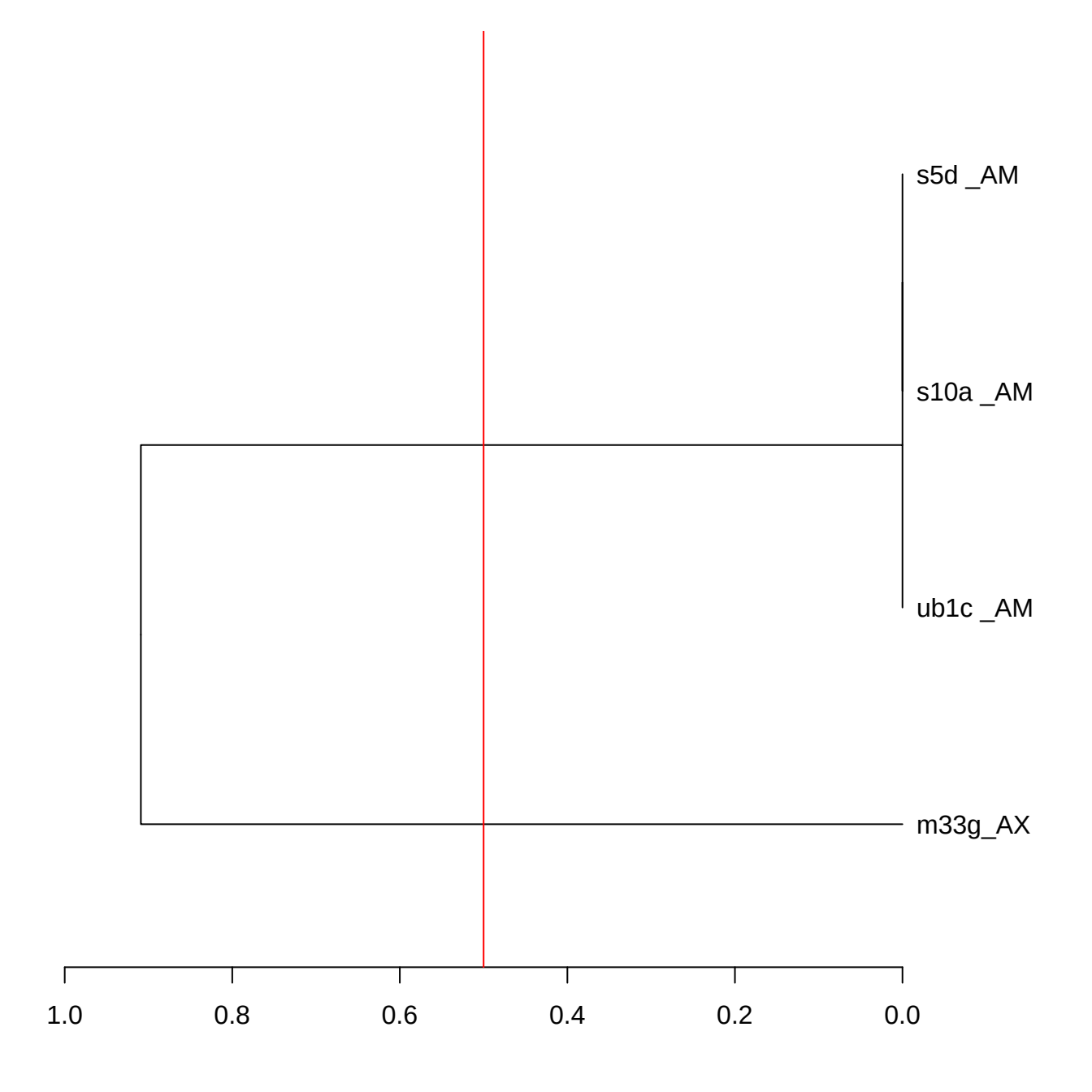
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s10a _AM
ub1c _AM
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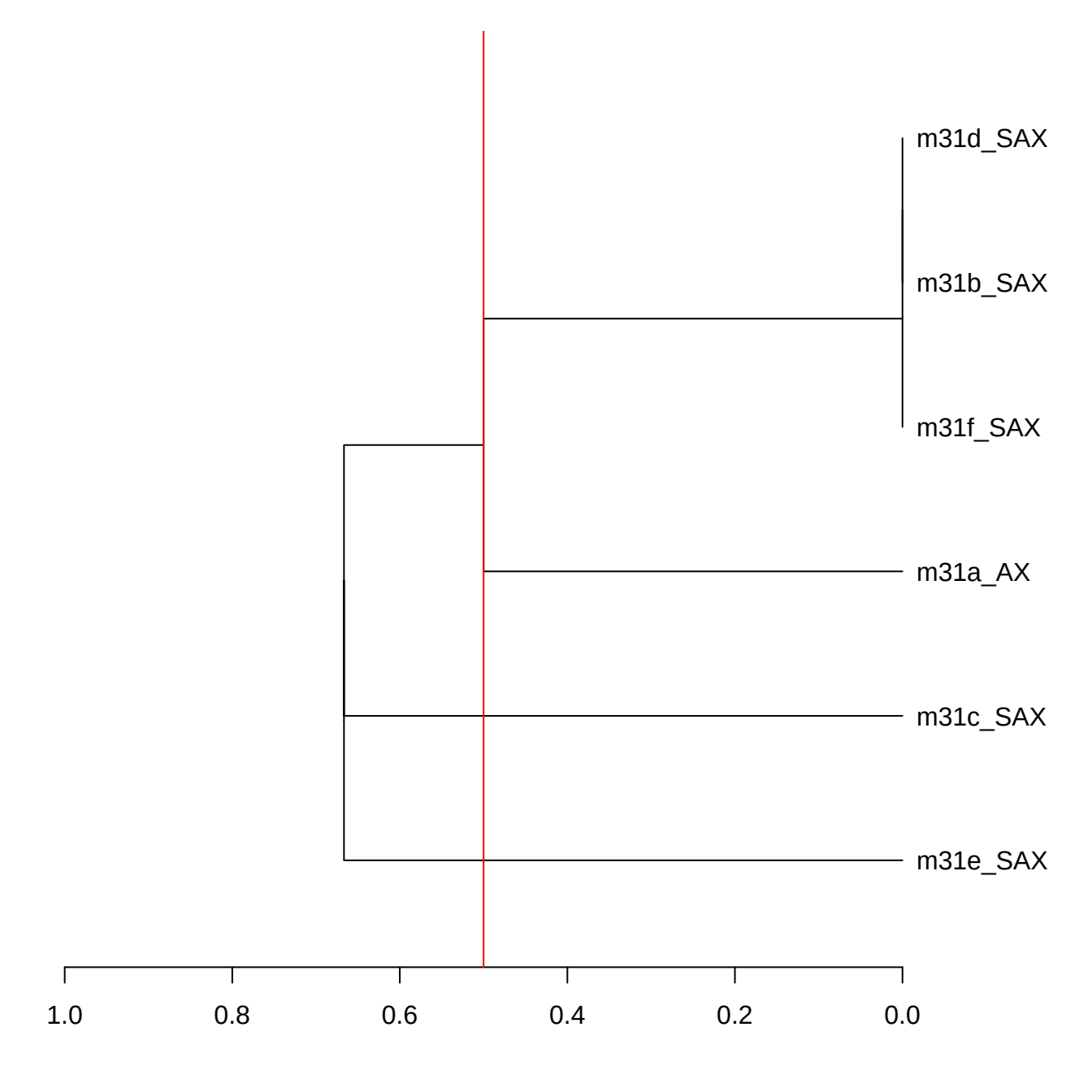
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m31b_SAX
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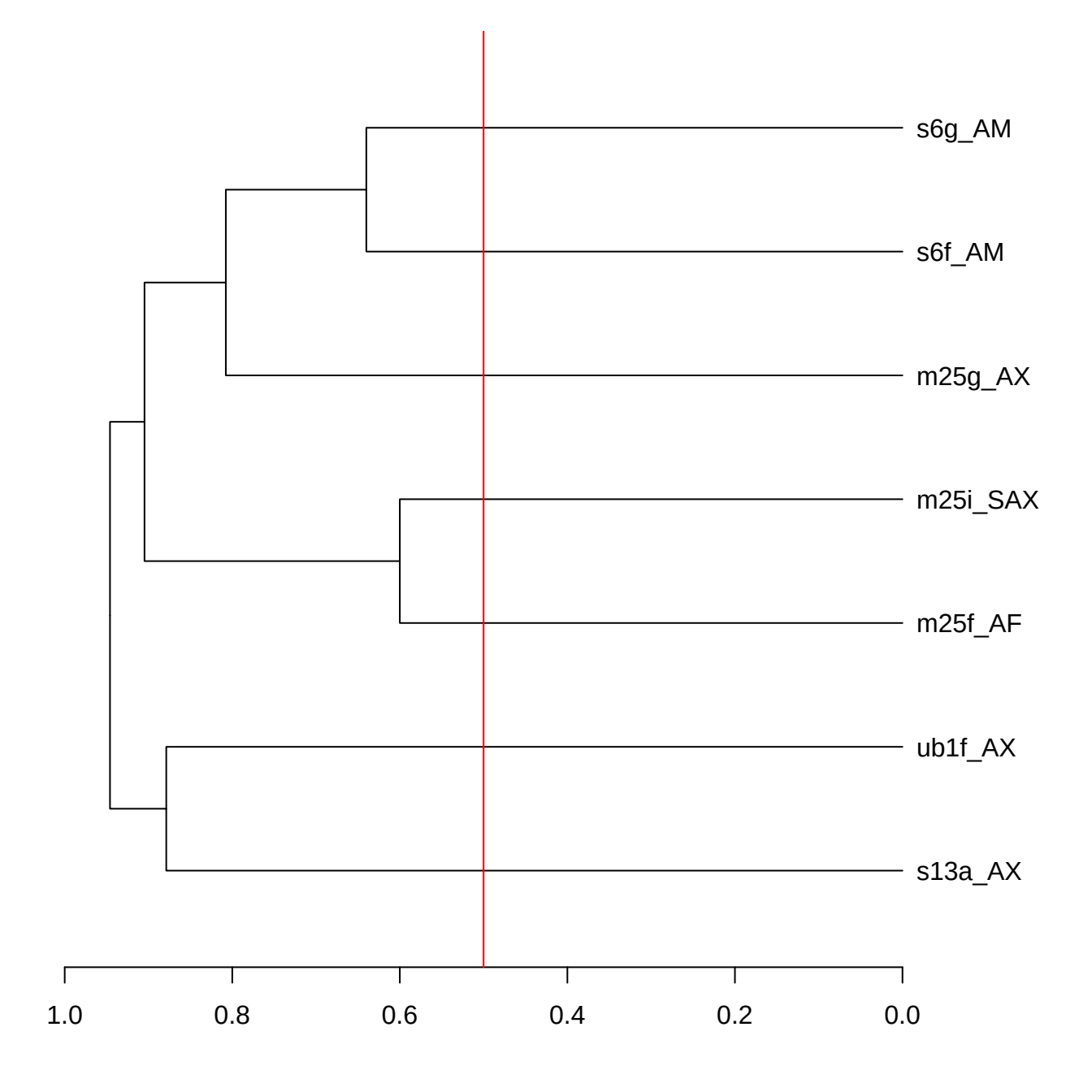
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s6f_AM
m25g_AX
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m25f_AF
ub1f_AX
s13a_AX
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0.2
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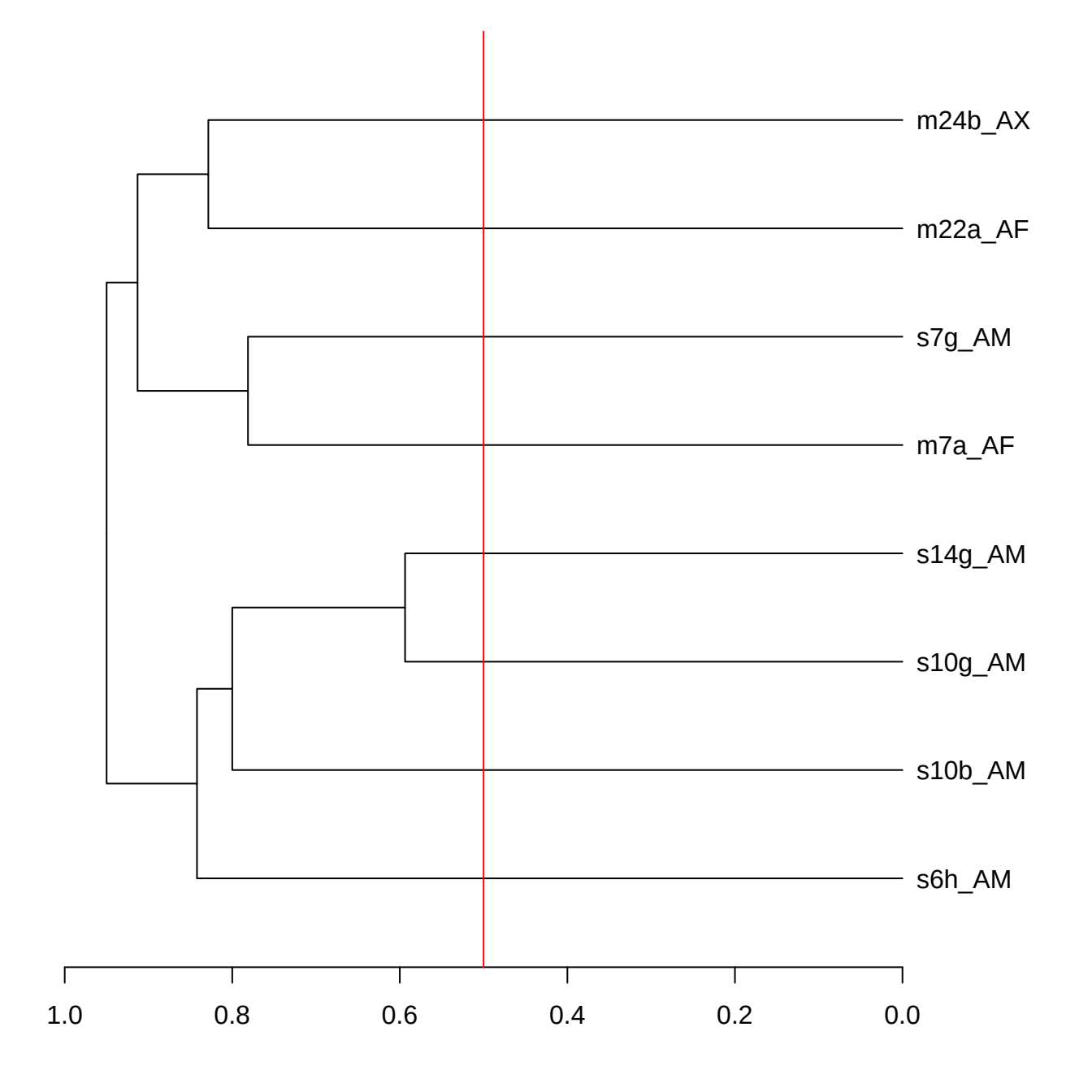
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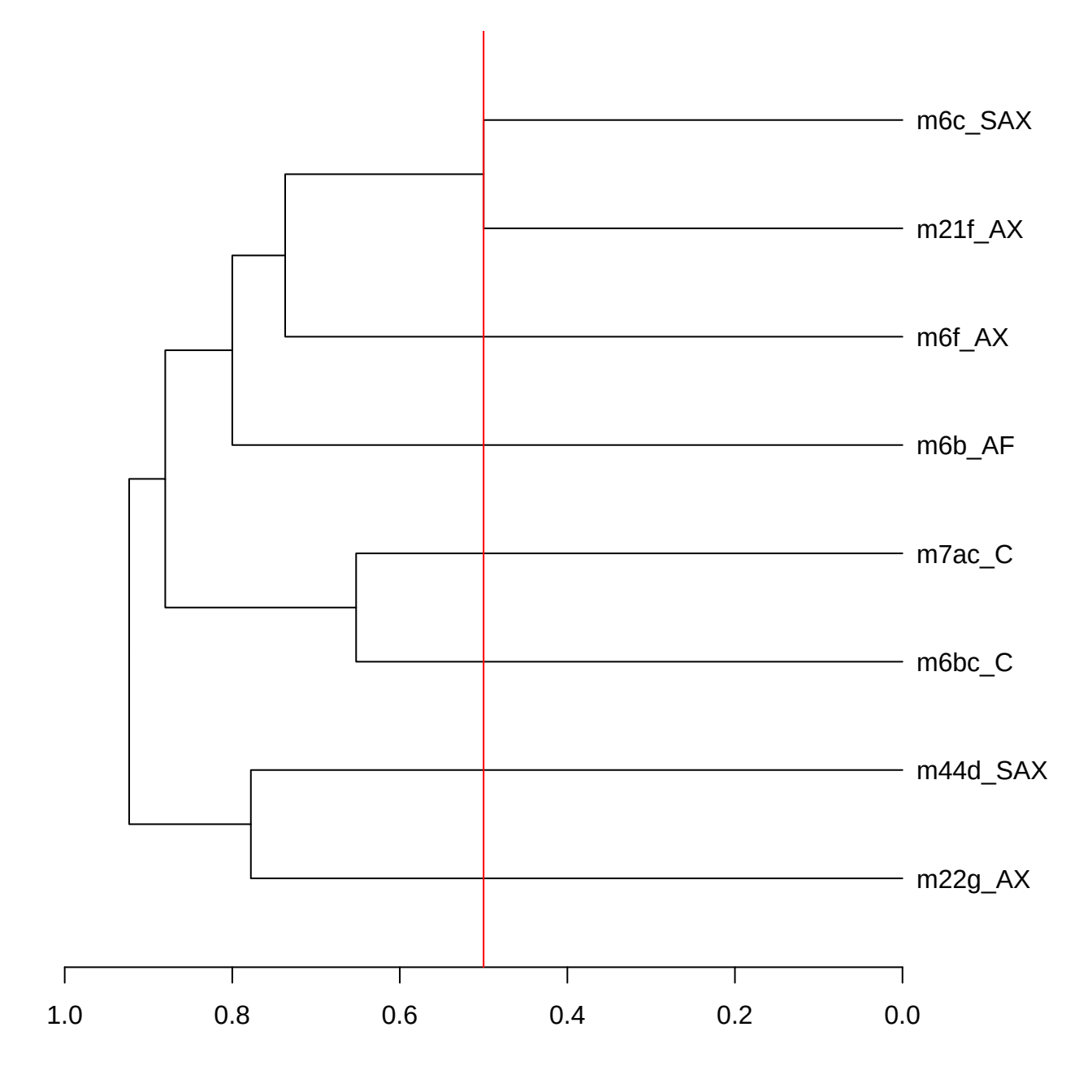
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m6f_AX
m6b_AF
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m22g_AX
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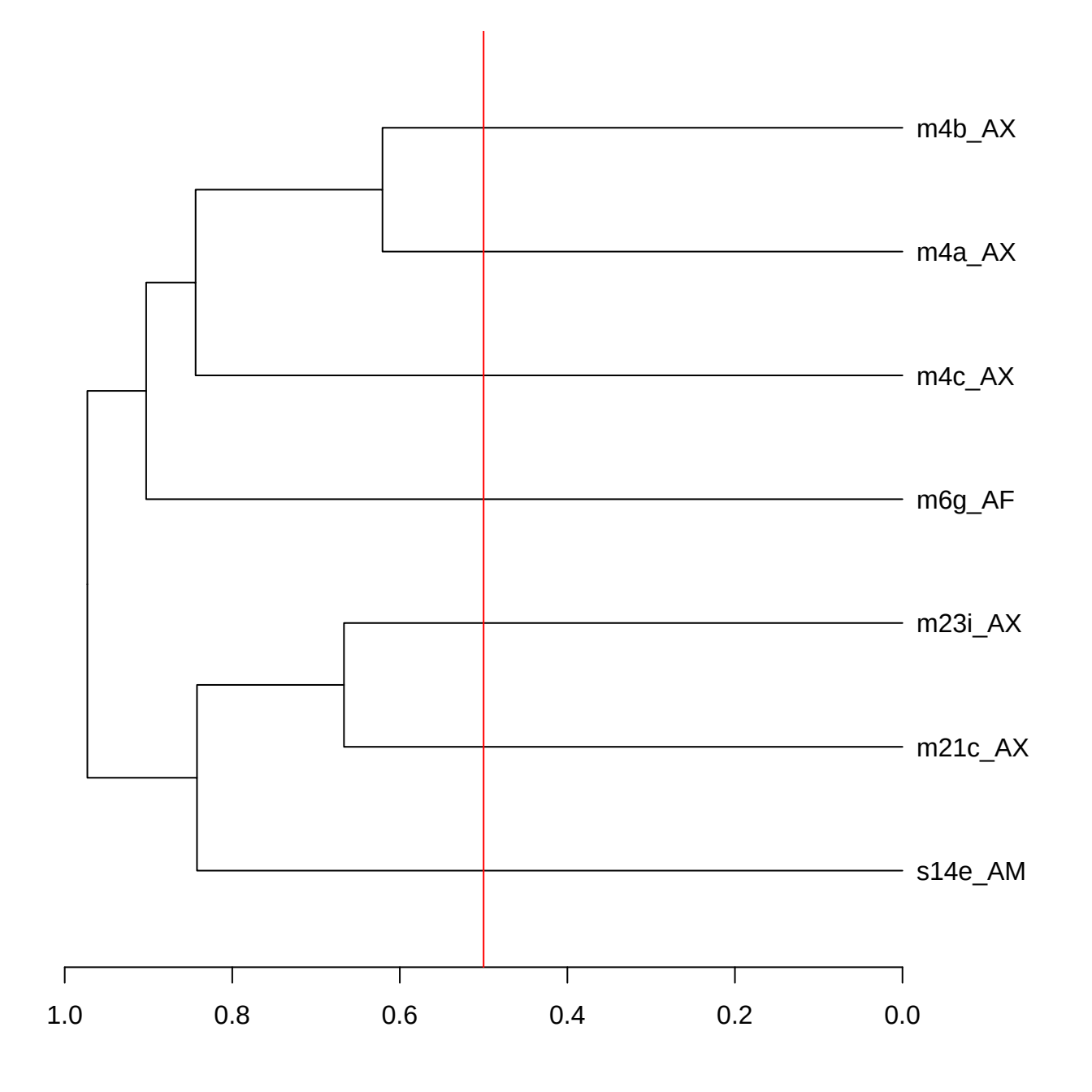
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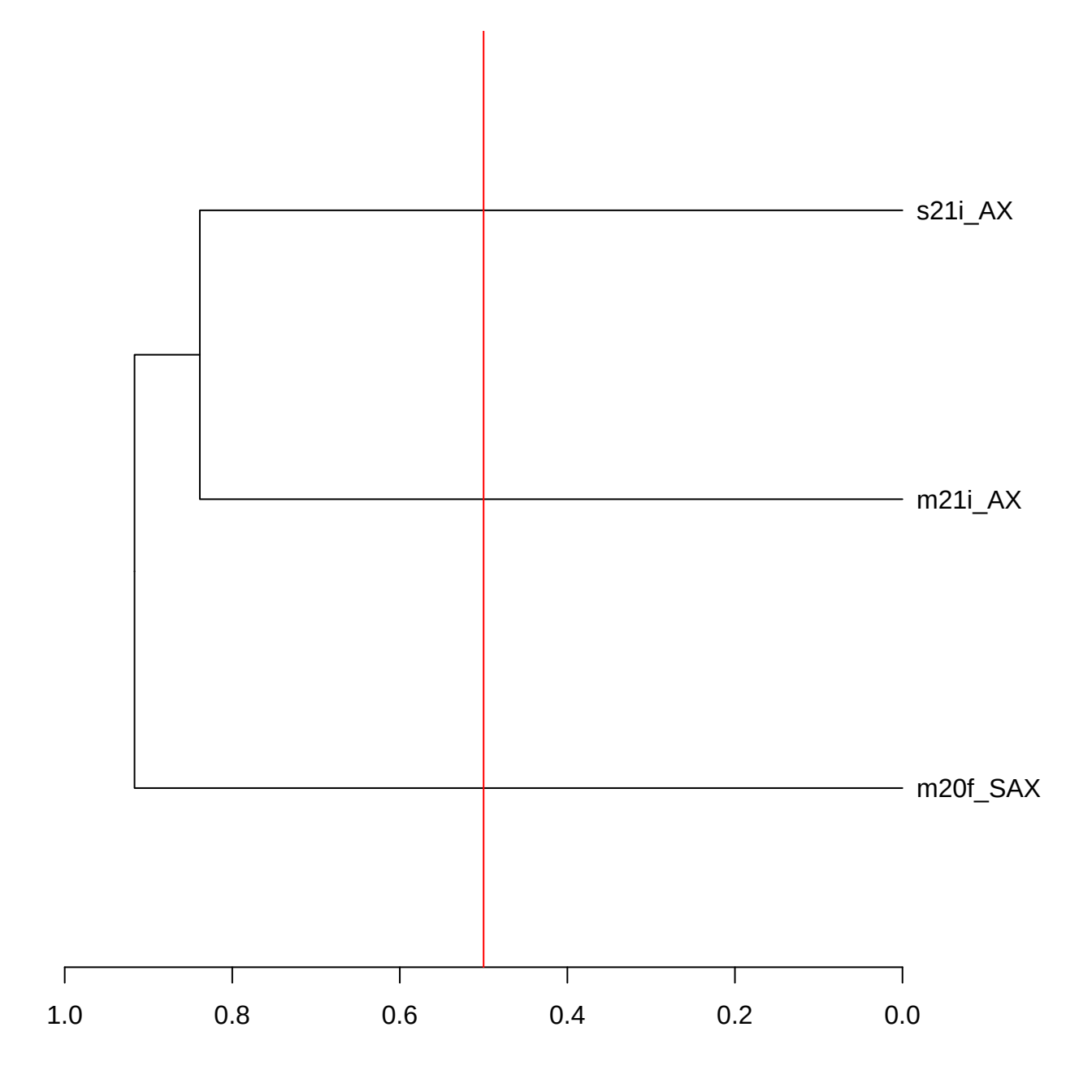
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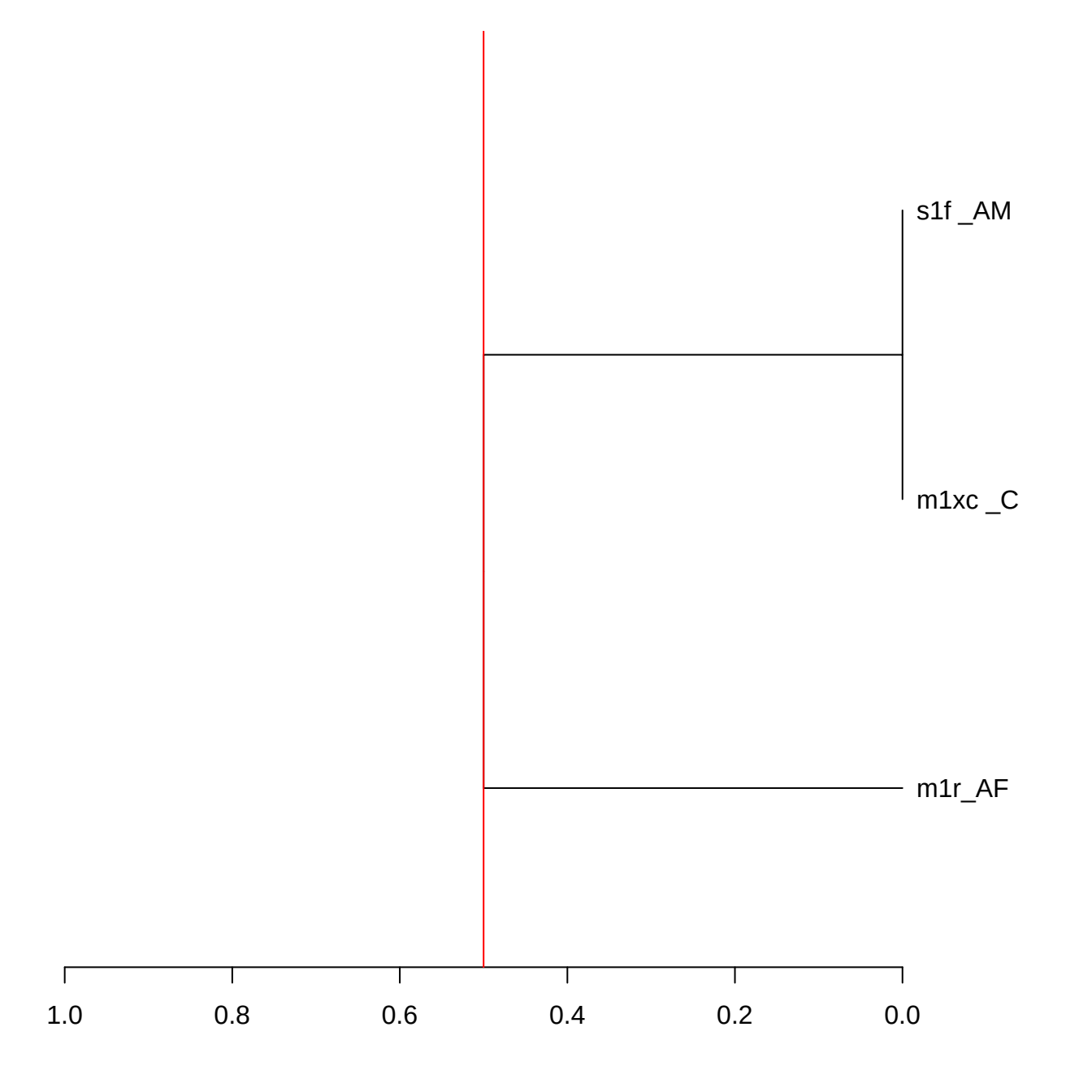
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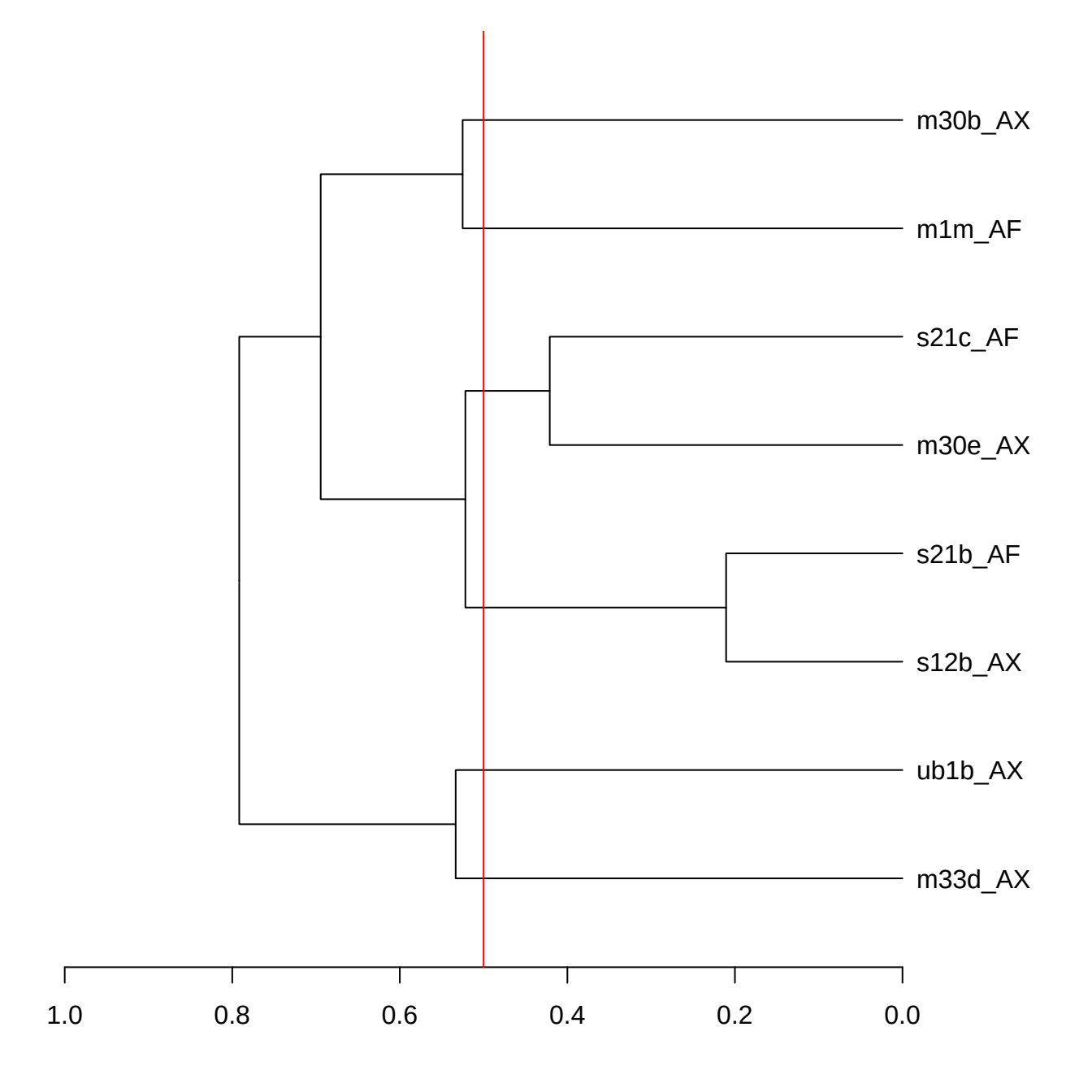
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ub1b_AX
m33d_AX
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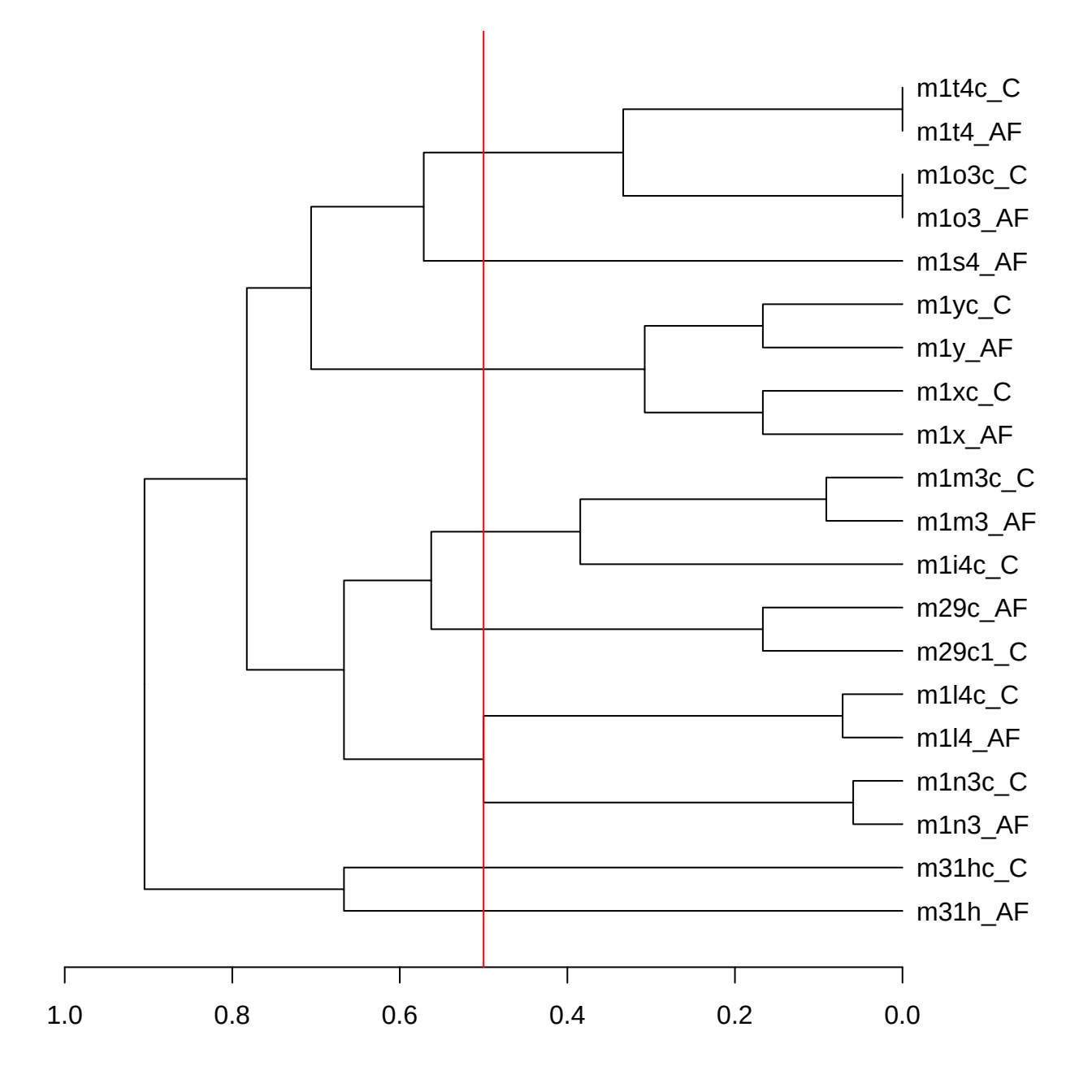
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m29c1_C
m1l4c_C
m1l4_AF
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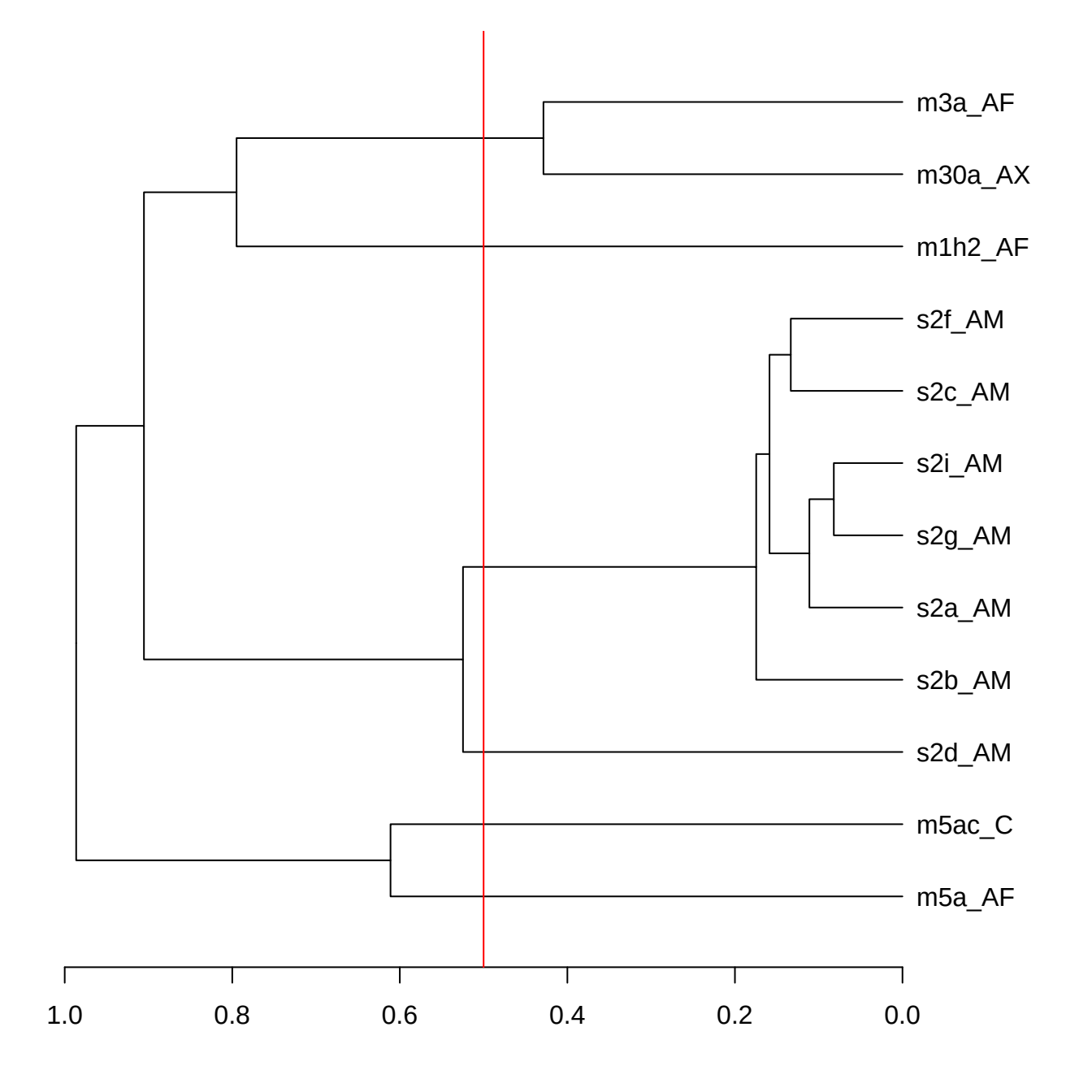
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s2c_AM
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s2g_AM
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s2b_AM
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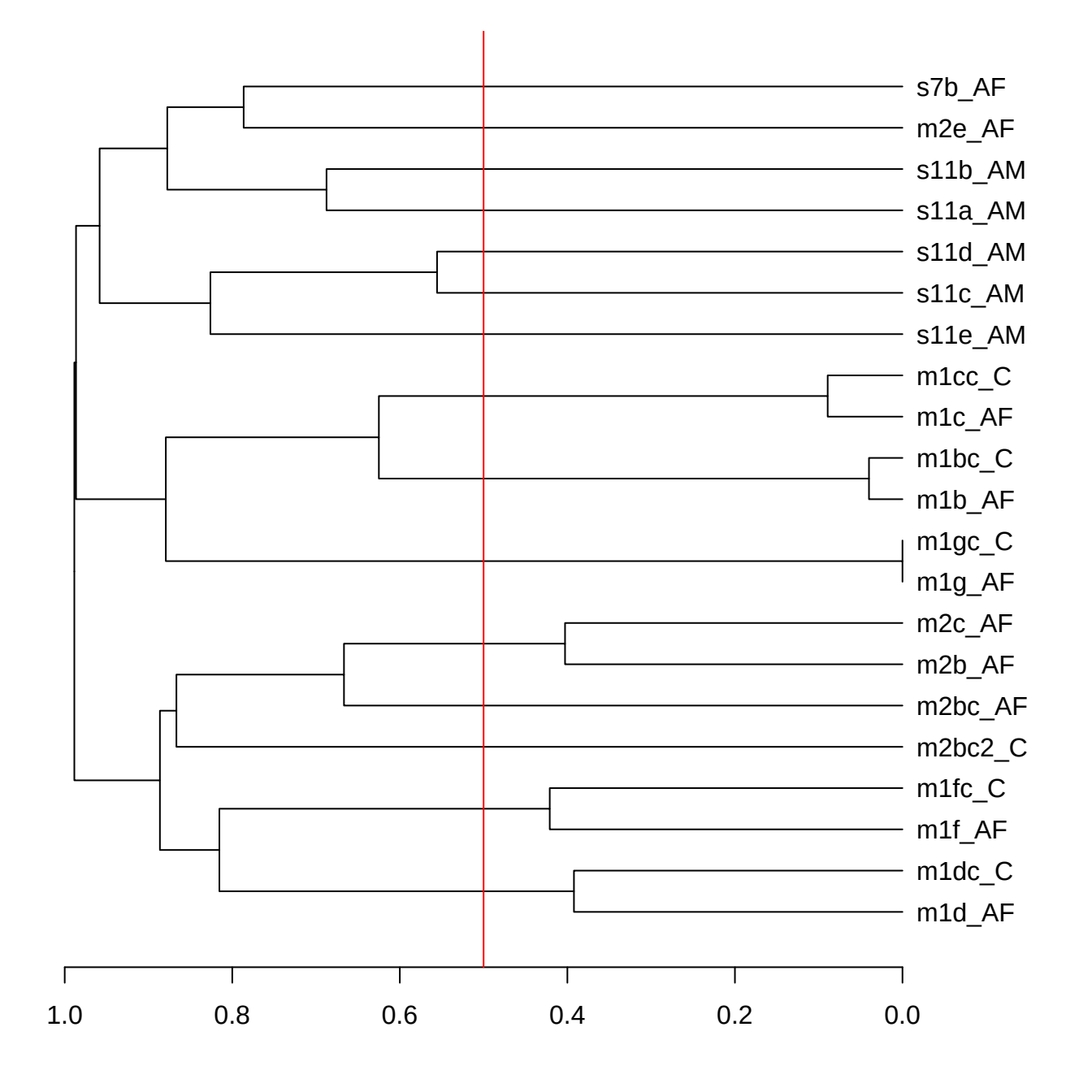
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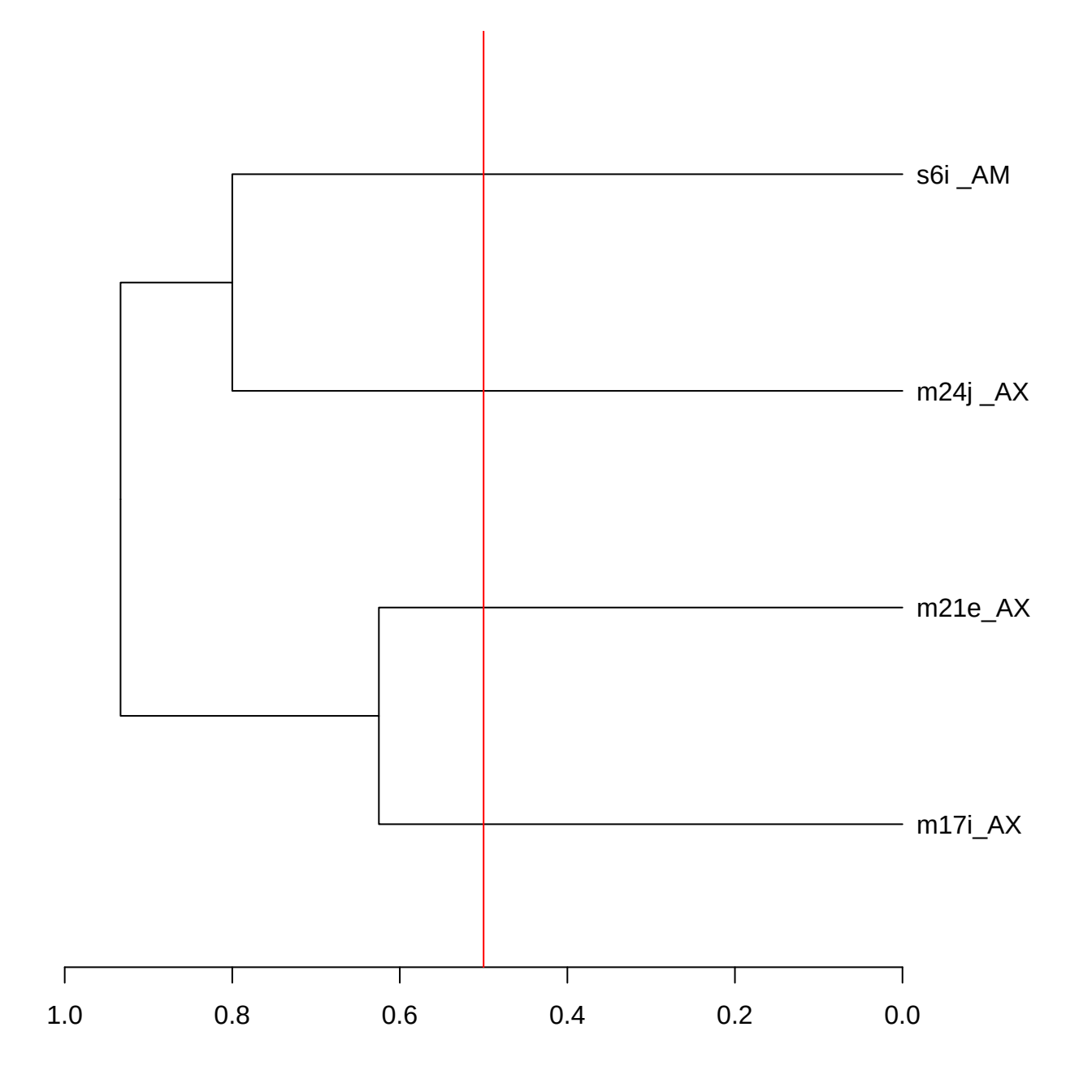
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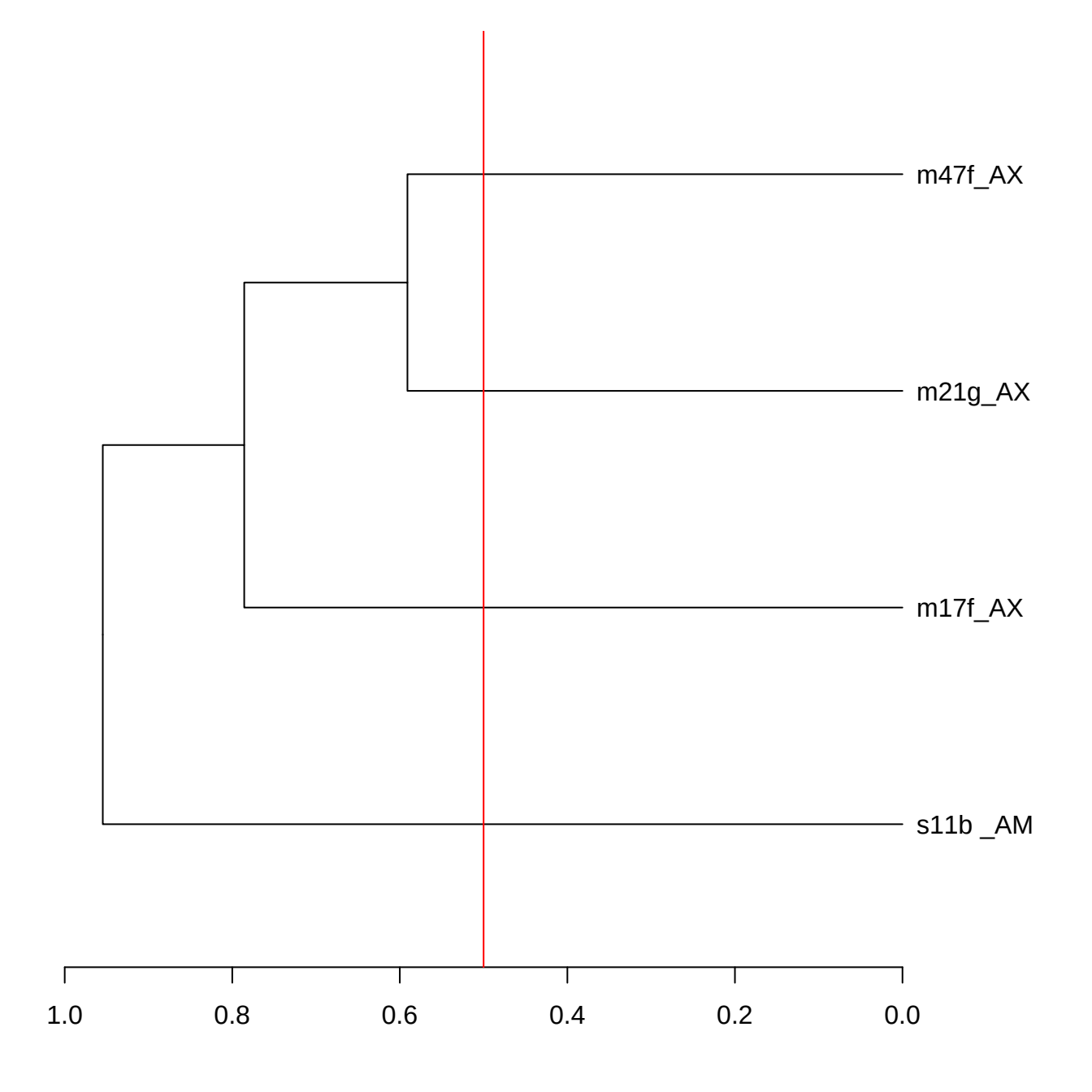
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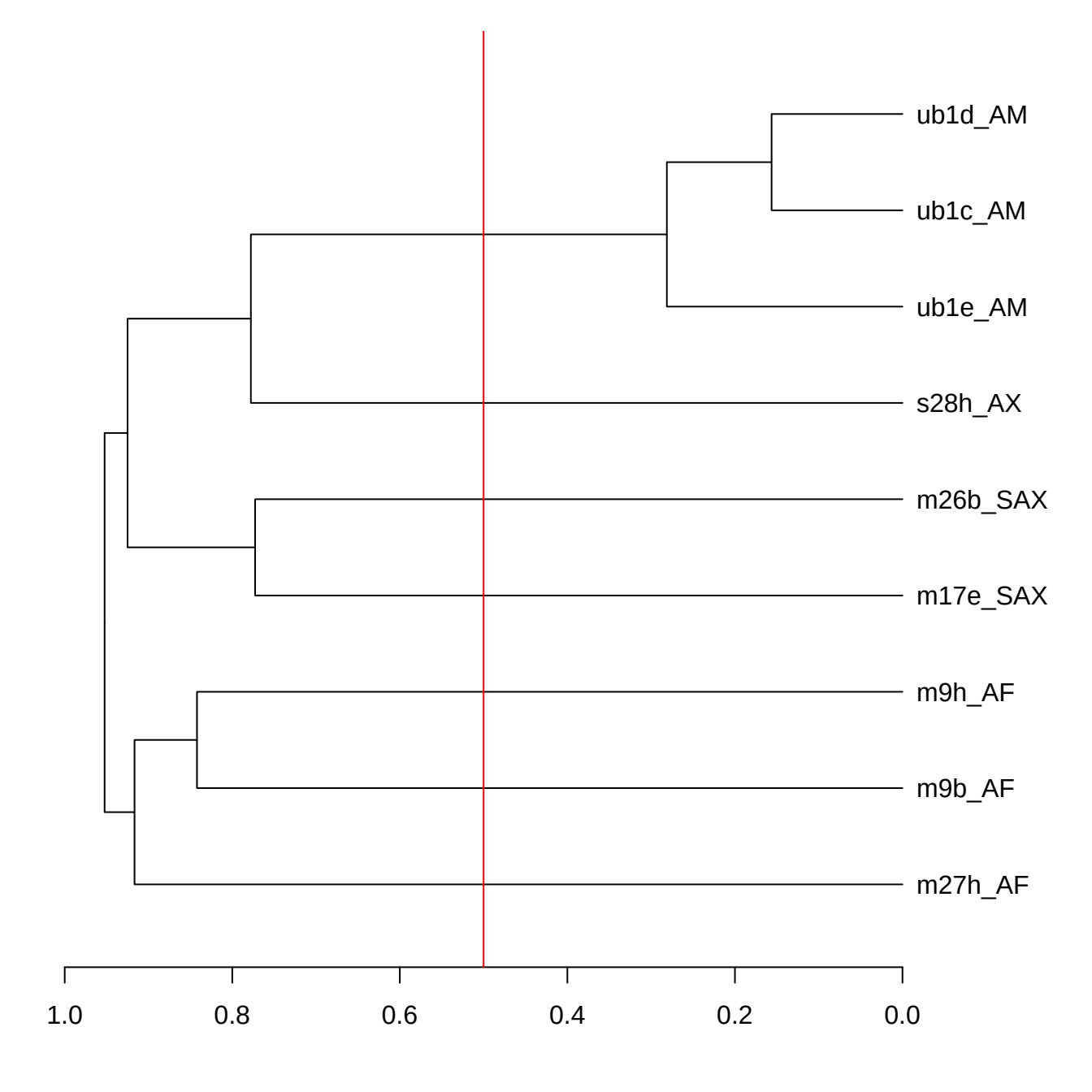
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ub1c_AM
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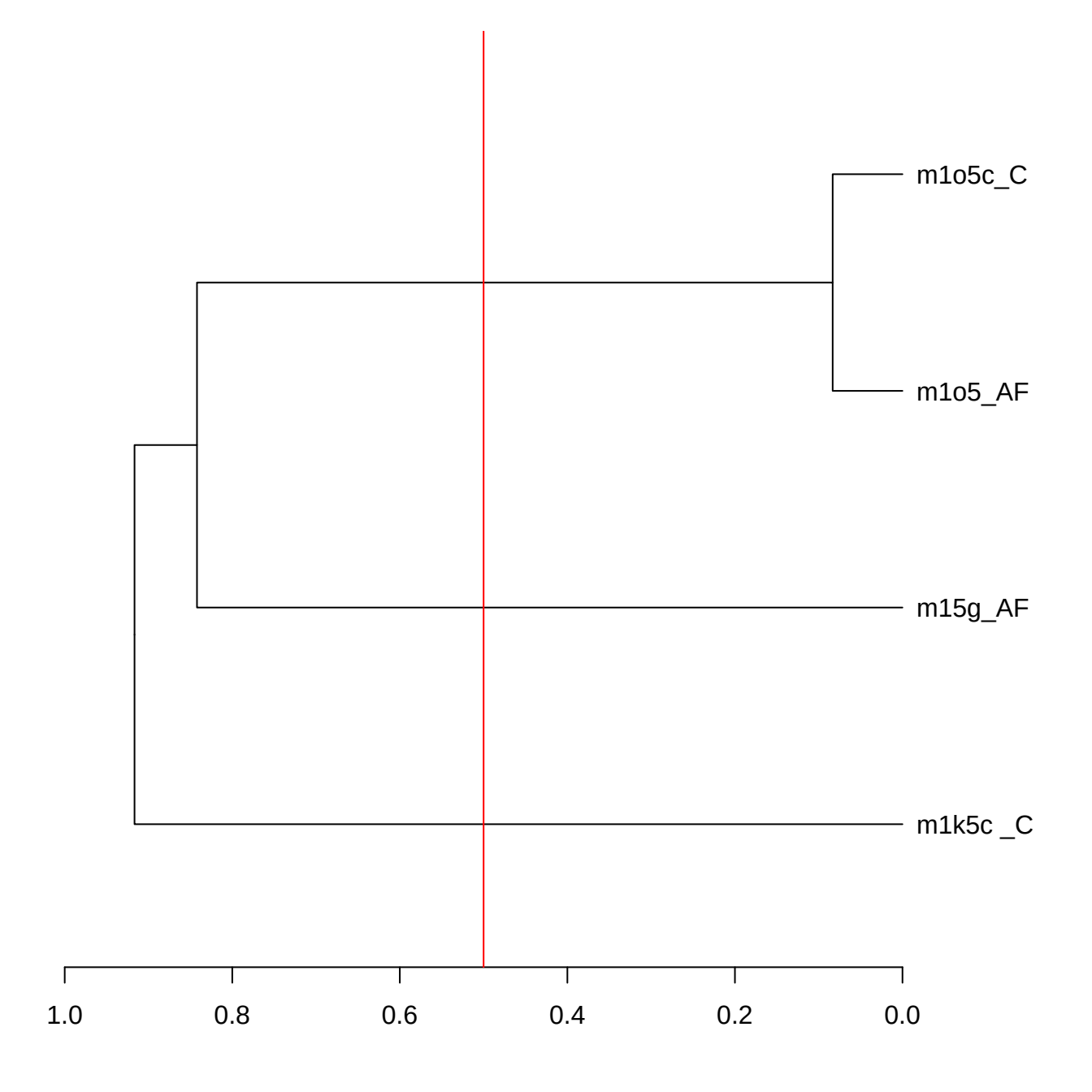
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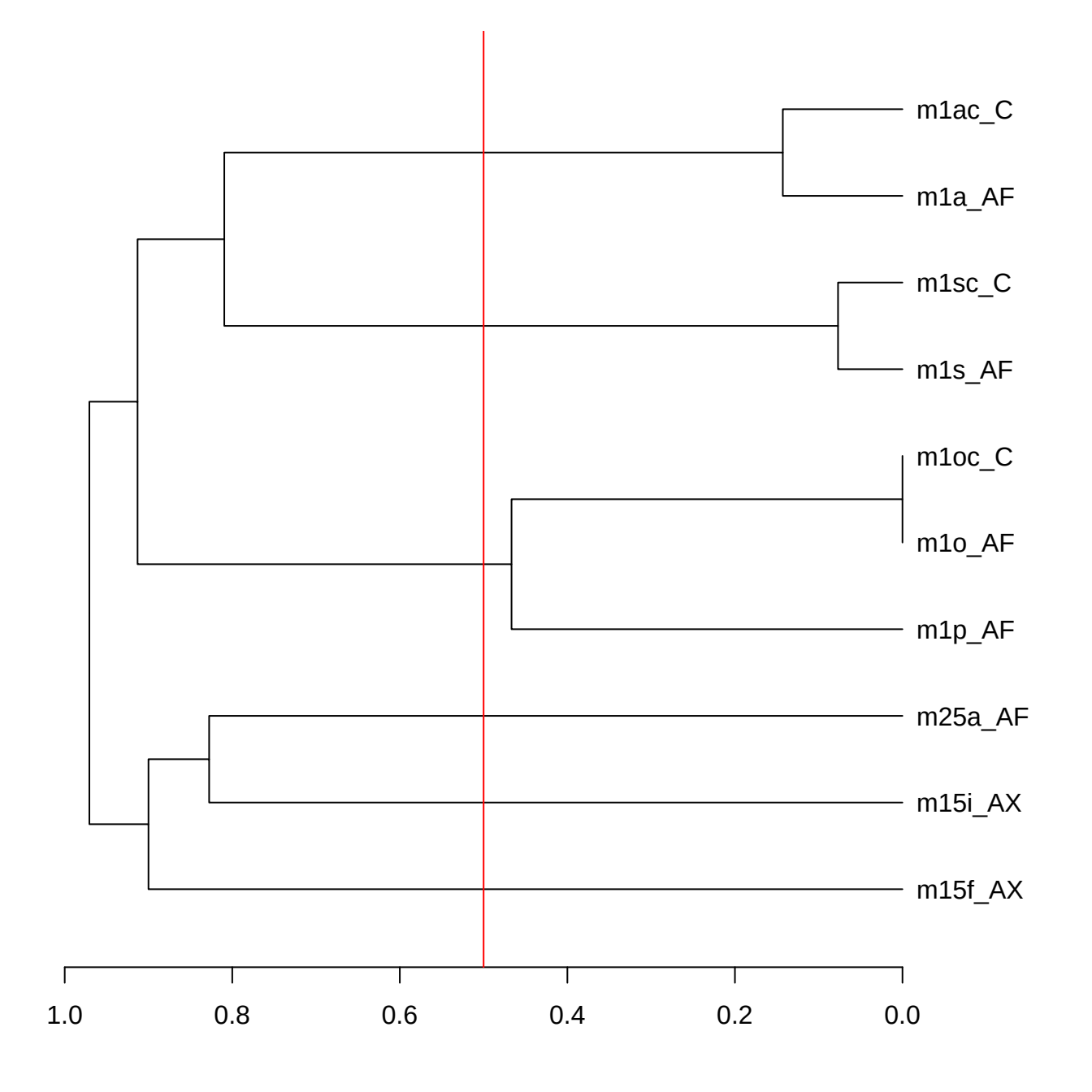
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m1oc_C
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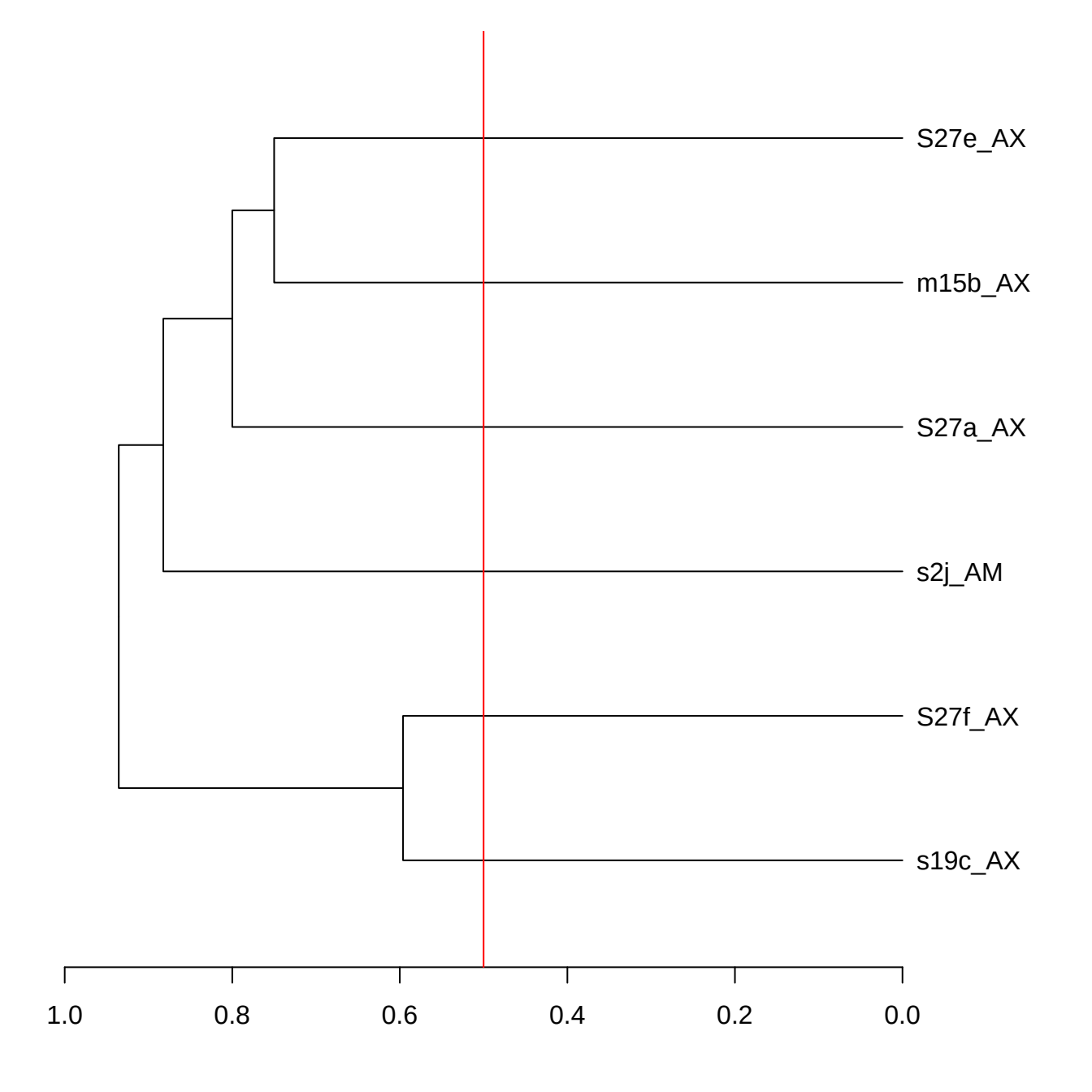
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m15b_AX
S27a_AX
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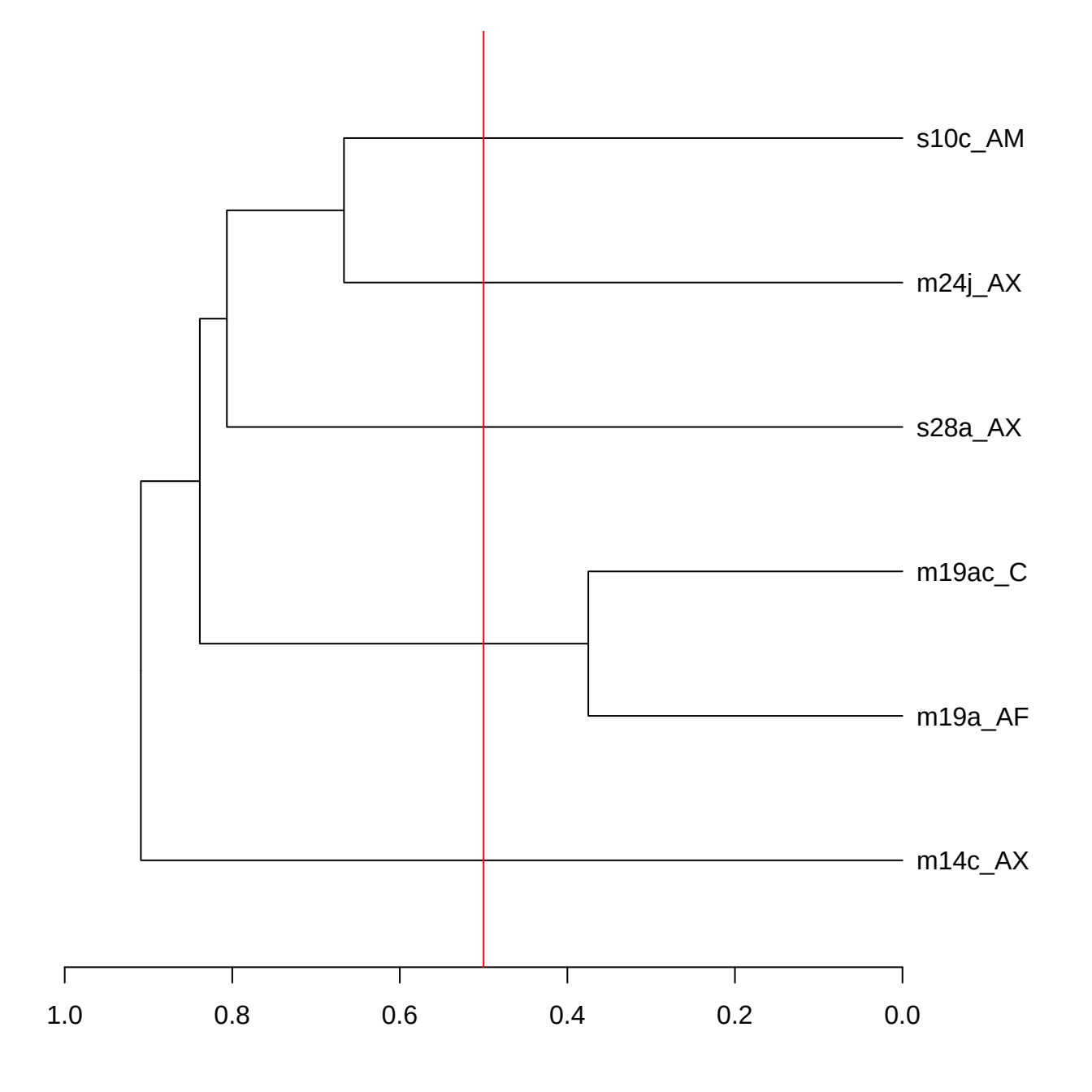
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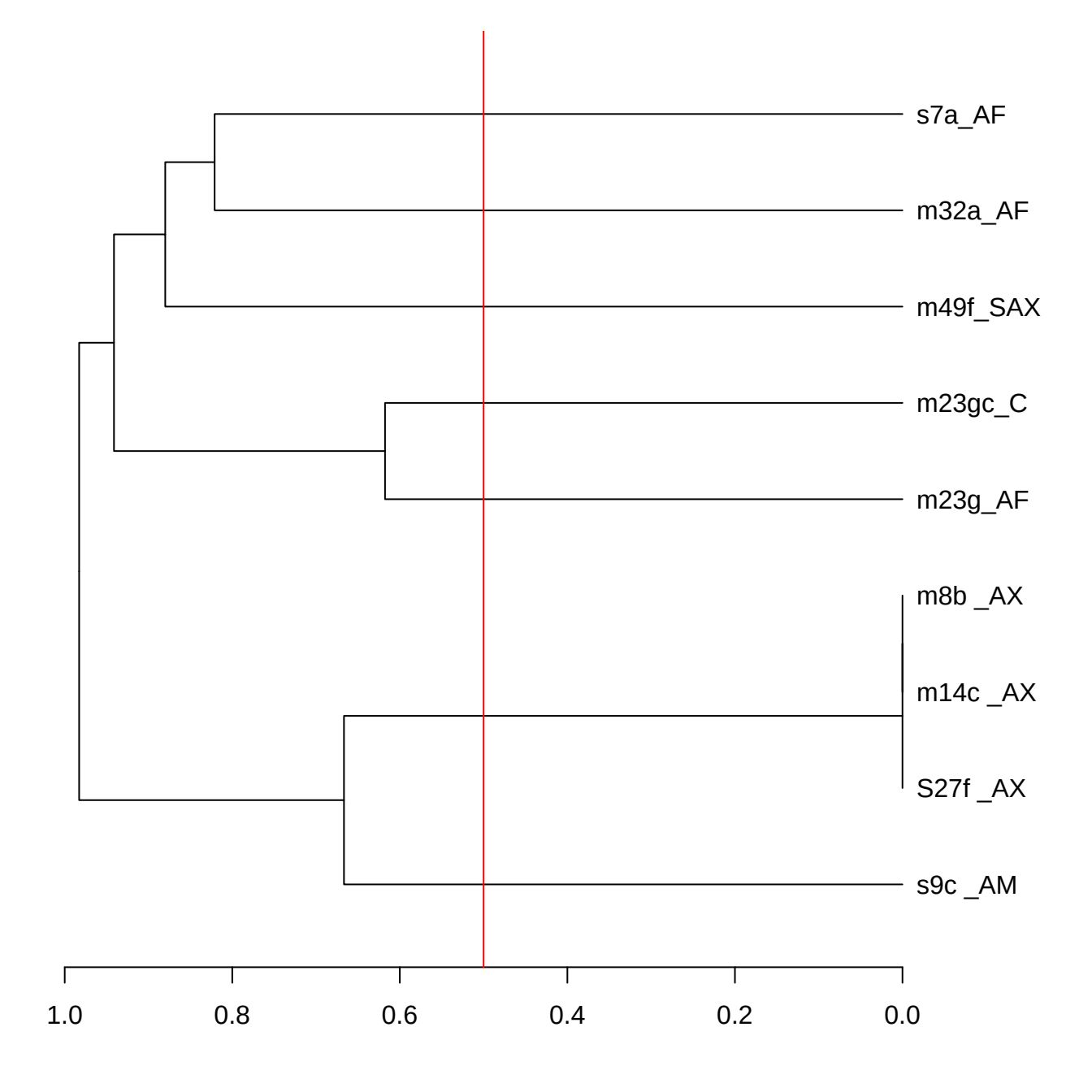
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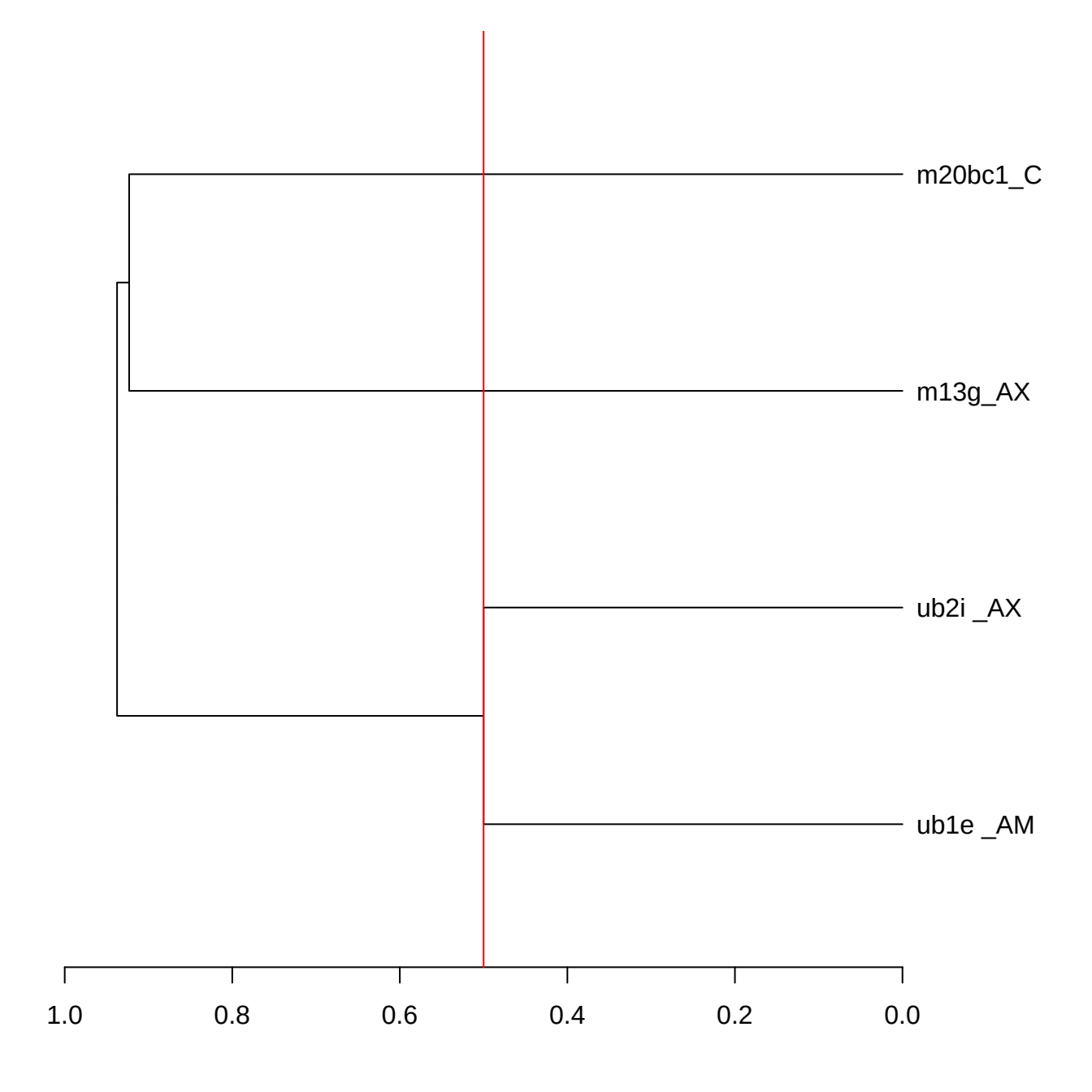
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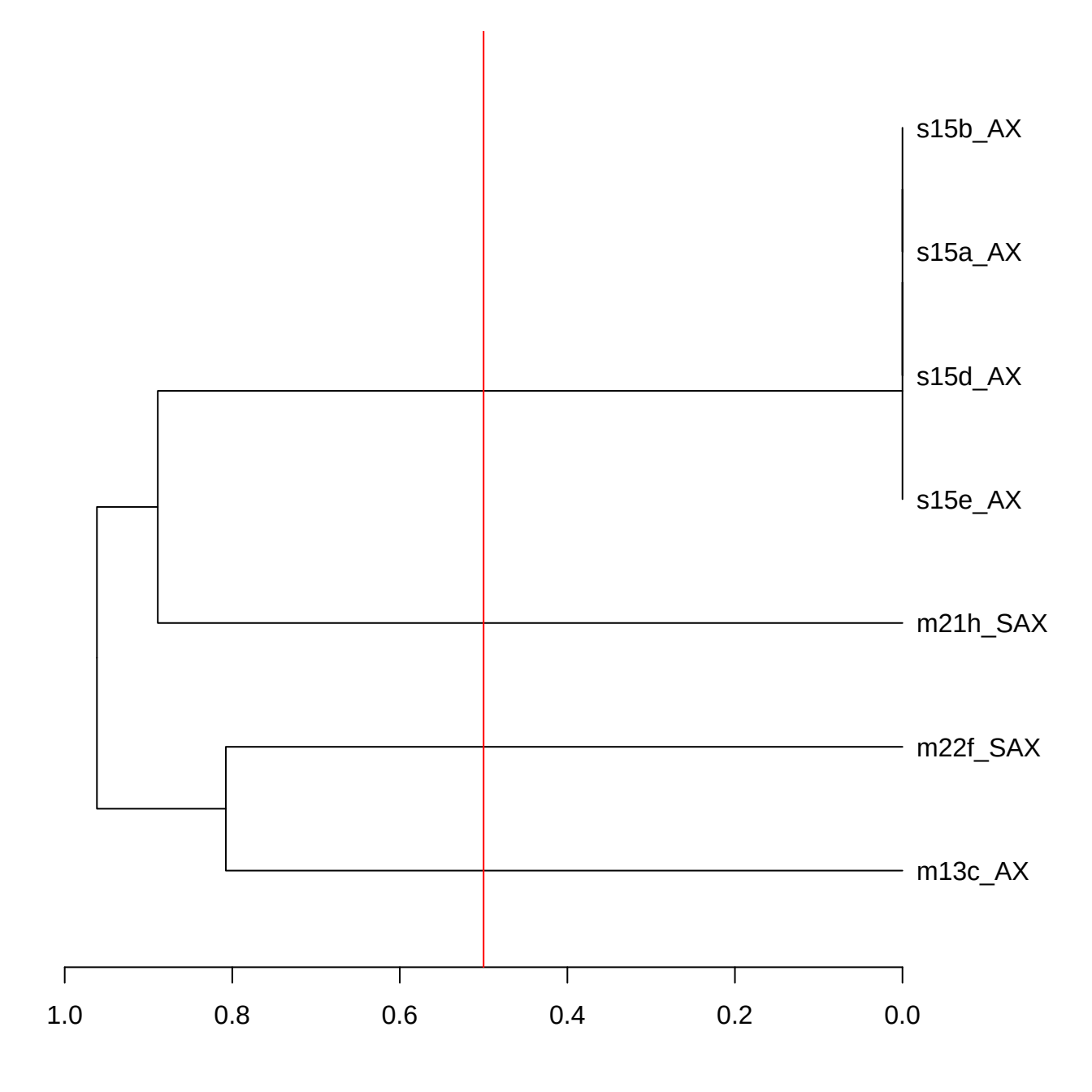
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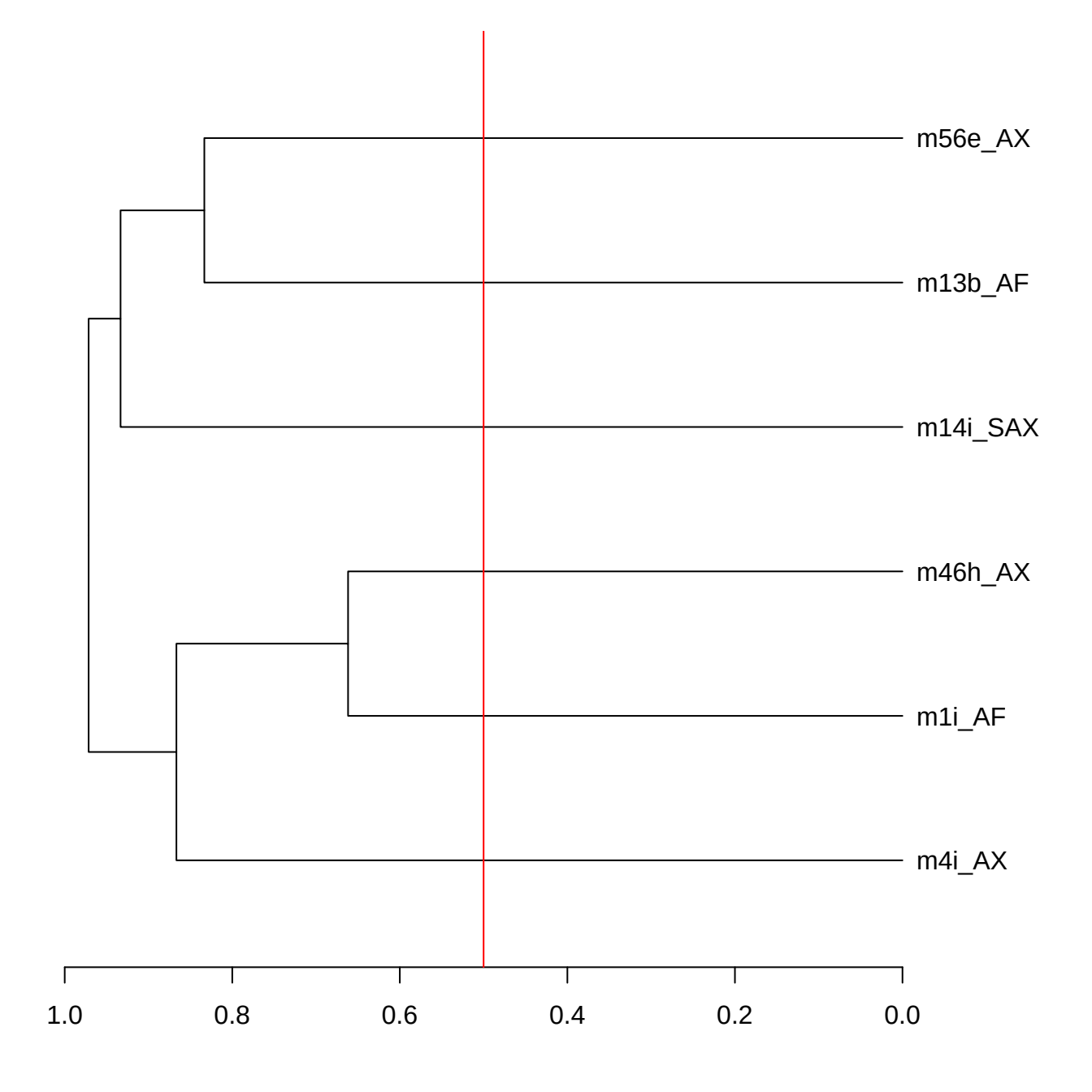
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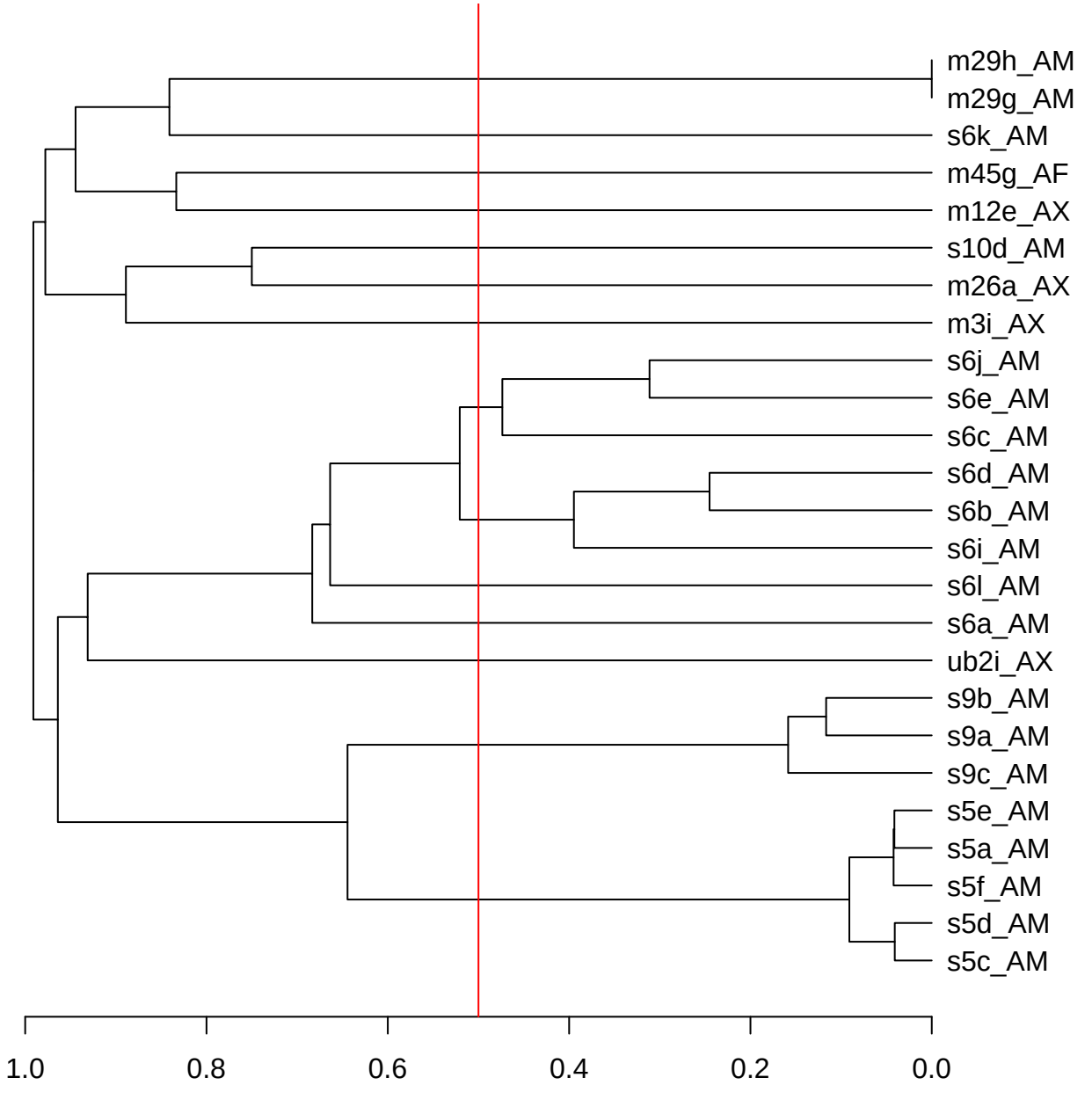
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s9b_AM
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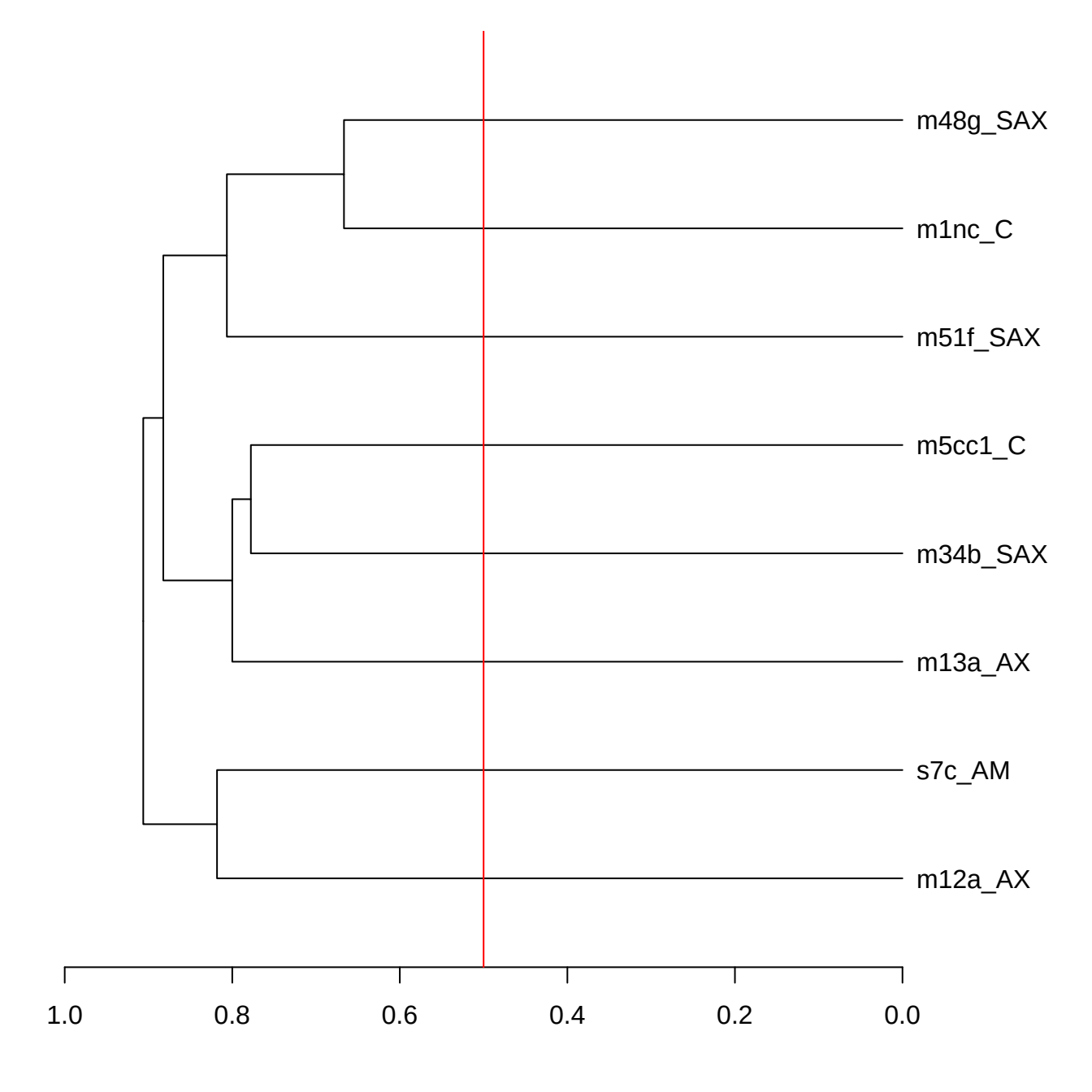
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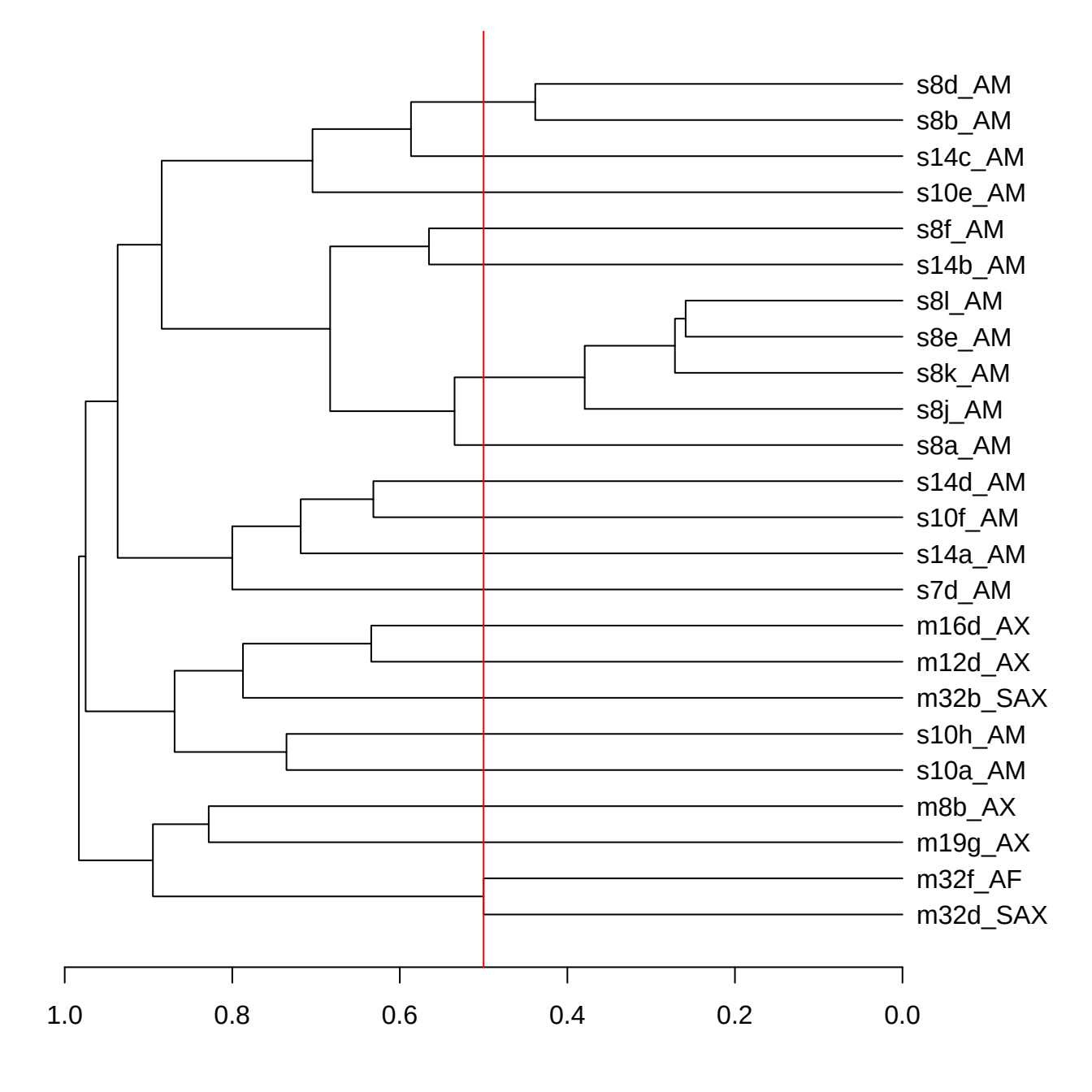
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