Purpose of the Research

The applicant shall indicate the general nature of the research and the specific purpose of the research, after succinctly summarizing it and providing an outline at the beginning, and with the existing academic literature referred to where necessary. In particular, details shall be given clearly with a focus on the following points. [Refer to the rules relating to the screening and evaluation for grants-in-aid for scientific research.]

1) Scientific background for the research (e.g., domestic and overseas trends related to the research and positioning of the research; how the applicant has reached the concept based on his or her achievements in earlier research work; and details of achievements of past research work where the purpose of this project is to attain a greater level of knowledge in a similar area)
2) What will be elucidated and to what extent will it be pursued during the research period
3) Scientific characteristics, originality and expected results and significance of the research in the area

Purpose of the Research (Outline)

*** Concerning the Purpose of the Research Project, the applicant should succinctly summarize and describe in detail.**

Marine dispersal barriers (MDBs) can result in genetic discontinuities between populations of organisms in the sea. Straits are a common type of MDB. Exactly how straits function as barriers has received little attention, although this knowledge is highly relevant to evolutionary and conservation biology, and predicting effects of climate change. We propose to focus on Tsugaru Strait in northern Japan as a model system to elucidate how straits act as barriers. We will examine the phylogeographic patterns of a taxonomically diverse selection of nearshore benthic algae and animals in the vicinity of the strait, including species representing various habitat preferences and life histories. Correlations between phylogeographic pattern and habitat or life history will shed light on the nature of straits as MDBs.

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1) Background. The connectivity, or degree of genetic exchange, among populations of marine organisms is a topic of high current interest, as it is relevant to evolutionary biology (allopatric speciation), biodiversity (prevalence of cryptic species), conservation biology (design of marine reserves, maintenance of genetic diversity, and dynamics of marine invasions), fisheries biology (diversity of commercially important marine organisms), and predicting the effects of climate change in marine ecosystems (how changes in current and temperature patterns related to global warming can affect dispersal patterns) (**refs. 1–8**). Factors reducing connectivity, leading to evolutionary and possibly adaptive divergence of populations (**ref. 9**), include low innate dispersal ability, isolation by distance, and marine dispersal barriers (MDBs) **(refs. 10–12)**. The relative importance of these factors in particular cases can make it difficult to predict the degree of connectivity among populations, and empirical results often do not match expectations (e.g., **refs. 13–15**).

Straits are a common and important type of dispersal barrier leading to population isolation and evolutionary divergence for terrestrial organisms in island archipelagos; well-known examples include the Galapagos, Philippine, Japanese, and Hawaiian Archipelagos. Straits can similarly function as barriers to marine dispersal, leading to speciation and local endemism (e.g., **ref. 16**; but see **ref. 17**), though this has been less well studied than in the terrestrial realm. The best-studied case of a strait as a MDB is the Central American Strait, which closed as the Isthmus of Panama 3.1 Ma (**ref. 18**). The strait functioned as a MDB between the Caribbean and eastern Pacific for millions of years as it grew progressively shallower prior to final closure (**ref. 19**).

Phylogeographic studies of marine organisms frequently invoke present-day straits (or land bridges spanning straits in the past) in an *ad-hoc* manner to explain genetic discontinuities between populations, yet how straits function as MDBs has received little attention — i.e., the relative contributions of physical attributes (depth, current & temperature patterns, habitat discontinuity) and biological attributes of populations (dispersal ability, habitat, seasonality) to divergences in evolutionary lineages. The Principal Investigator first began to think about straits as MDBs in a phylogeographic study of bryozoans on both sides of the Isthmus of Panama (**ref. 20**). Results from two subsequent studies led to the realization that much smaller straits can function as MDBs, yet have scarcely been studied in this regard. One study detected apparently local species radiations in two unrelated genera of deep-shelf bryozoans (**refs. 21, 22**) in the Aleutian Island archipelago, and one species showed morphological (and presumably genetic) differentiation along the archipelago, i.e., incipient allopatric speciation. Neither differentiation nor the high number of local endemics can well be explained unless some of the numerous Aleutian straits are acting as MDBs. Another study (Dick et al., unpublished data) detected populations of the cheilostome bryozoan *Cauloramphus multispinosus* east and west of Tsugaru Strait that are morphologically identical but genetically divergent by 11% (K2P) for COI, suggesting that this strait has long constituted a MDB for this lineage.

Here we propose to focus on a single strait (Tsugaru Strait between Hokkaido and Honshu Islands, Japan) as a model system to understand how and the extent to which straits act as MDBs. Tsugaru Strait is ideal for this study. It is relatively small (73 km long between western and eastern necks; 18 km wide at

Purpose of the Research (continued)
narrowest point) and shallow (shallowest sill depth, 140 m). It is the major strait separating the North Pacific from the marginal Sea of Japan, with environmental differences between the two. As is typical of oceanic straits, current patterns are predominantly oceanic rather than tidal, and are directionally biased: a branch of the warm Tsushima Current flowing northward in the Sea of Japan exits from west to east through the strait as the Tsugaru Current, which merges with the cold Oyashio Current flowing south in the Pacific, forming a gyre east of the strait. The oceanography (**refs. 23–26**), paleoceanography (**refs. 27–31**), and geology (**refs. 32–35**) of Tsugaru Strait have been well studied. Finally, several previous studies indicate that Tsugaru Strait acts differentially as a barrier to populations of benthic species having different life histories (e.g., **refs. 36, 37**).

2) What will be elucidated. The basic design of the study is to examine, in the vicinity of Tsugaru Strait, the molecular population structures of a variety of nearshore benthic marine species representing a range of habitat requirements, life histories, and dispersal capabilities, and to use standard phylogeographic and population genetic analyses to detect and quantify genetic discontinuities (or lack thereof) between populations and the geographic pattern of these discontinuities. In terms of results, the study will minimally be able to compare population structures among species and to correlate these structures with geography. Rather than interpret each phylogeographic pattern on an *ad-hoc* basis, we will use all available physical data on the strait and biological data on each species to predict expected patterns *a priori*. Congruence between hypothetical and empirically determined patterns will indicate that our initial assumptions about how the Strait functions as a MDB were correct. Shared assumptions between pairs of species that contradict predictions will allow us to identify particular faulty assumptions, and revised hypotheses for non-congruent species can be tested with future research.

Tsugaru Strait has a complex geological and paleoceanographic history. Present-day oceanographic conditions in the strait have existed only for roughly the past 8000 years. During some previous intervals, the Tsushima Current did not exist (95–27 ka); during others, the cold Oyashio Current flowed westward through the strait (17–10 ka). Tsugaru Strait became much shallower during each glacial maximum throughout the Pleistocene, but it remains controversial how many times or even whether the Strait formed a land bridge between Honshu and Hokkaido (c.f. **refs. 38–41**). None of these historical episodes precludes Tsugaru Strait from having acted as a MDB in the past, and at times more strongly than now (as when the strait was a shoal area or land bridge). Present-day genetic discontinuities in populations around the Strait will certainly reflect historical events pre-dating 8000 years, though different species may have responded differentially and at different times. Using molecular clocks, we will be able to estimate when populations began to diverge, thus gaining insight into the timing of key geological / oceanographic changes leading to divergence, which will shed light on key factors contributing to the MDB.

3) Characteristics, originality and significance. Many studies have examined the effect of differences in life history (dispersability) on degree of population discontinuity (e.g., **refs. 2, 13, 42, 43**). A few studies have used a comparative approach to examine population discontinuities across broad zoogeographic boundaries or entire oceans (**refs. 15, 44, 45**). Our proposed study is novel, as it is the first to focus on a single, well-characterized strait as a model system, and the first to investigate a MDB by comparing a broad range of taxonomically and ecologically diverse species. Given the vast number of straits worldwide that can potentially act as MDBs, the results will have global theoretical and practical significance.

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