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CONTENTS

CLIMATE ECOSYSTEM

MATERIAL KIN: FASHIONING A CELLULOSE-BASED FOAM FLOATATION DEVICE IN CLIMATE BREAKDOWN

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Abstract
Devastating bushfires and flooding have been ravaging the eastern and southern states of Australia since 2019. Living in Australia amidst climate breakdown demands we transition towards regenerative and sustainable material systems, but the challenge posed to designers is how do we design without extractive and exploitative processes? How do we make kin with new materials? Responding to this context, this paper highlights an alternative mode of interaction between materials and designers and shows how a critical design piece can emerge from practice-led research that promotes material kinship. I have developed the Material Kin Relational Ontology (MAKRO) – a framework that promotes a way of working and collaborating with materials and processes where ingredients, materials, and myself are all considered kin. Being kin implies relationships of reciprocity and care, which in the context of bio-based materials design can mean cultivating, cohabiting, and regenerating. This paper will position MAKRO in context and conversation with the *Earth Logic: Fashion Action Research Plan* (Fletcher & Tham, 2019), Haraway's (2016) string figures, Bennett's (2010) *Vibrant Matter* and Stengers' (2018) manifesto for slow science. It will present a case study of MAKRO in action, showing the development of novel cellulose-based foam materials which are then fashioned into a critical design object – a biobased and biodegradable lifejacket responding to Australia's rapidly rising flood waters. The lifejacket is intended to trouble the distinction between a product and a critical design object: it provides buoyancy, but it also prompts those who encounter and use it to imagine a post-petrochemical materials world, a future where we show responsibility and care towards the world and material kin.

Author Keywords
Design research; materials; materiality; ontology.

Introduction
Summer 2019, on the east coast of Australia: the air was thick, smoky and insidious, the sky orange. Sirens wailed from police cars and fire trucks raced down the highway in the opposite direction. We had chosen to cut our holiday short and get out while we could. The beach had not provided comfort; ash and burnt leaves floated on the surface of the water and sand. Growing up in the blue mountains west of Sydney prepared me for this scenario, as bushfires were a present and lurking threat. Sandbags were handmade by neighbours/residents to plug gutters, sprinklers were installed on our roof, hoses were at

the ready. However, this summer, for many people, such preparations proved inadequate against the intensity of the fires. Three years later, and during the last week in February, we experienced the wettest seven-day period on record, with over 50 sites in northern New South Wales (NSW) and southern Queensland measuring over 1000 millimeters in rainfall (Australian Bureau of Meteorology, 2022). Lismore, a town in the eastern state of NSW, has now endured two catastrophic floods in under two months. Thousands have been left homeless. Brisbane and parts of Sydney were also severely impacted by flooding. Images of people seeking refuge on the roof of their homes, wet and cold, waiting to be rescued by boats or helicopters were broadcast by Australian mainstream media.

The climate is breaking down because of our reliance on fossil-derived materials and our habits of overconsumption. It has become apparent to many Australians that we need to adapt by reducing our consumption of goods as well as changing our unsustainable material systems. A reduction of resource consumptive actions by at least 75% is required for us to live within the earth's means (Fletcher & Tham, 2019) in order to match our resource consumption to the earth's resource production. Changing our current material systems to produce biobased materials that are sustainable, regenerative, and repairable is one way that we could lower our material footprint so that we can live through climate breakdown and fashion a recuperation of earth.

Designers are still working out our role in this transition. For some of us, this means relearning how to work with biobased, living, and regenerated materials. This paper outlines a methodology relevant to both professional designers and citizen designers working with materials and shows this methodology in action through the development of cellulose-based foam materials. The methodology demonstrates how we can make kin with biobased materials[1] to help us imagine designing without extractive and exploitative processes.

MAKRO

Material Kin Relational Ontology (MAKRO) is the methodology that I have developed and is a way of working and collaborating with materials and processes. The philosophical underpinnings for the MAKRO are mostly concerned with ontology (what exists) and phenomenology (what is experienced) (Smith, 2018). Ontological systems provide classification of a thing, a manifestation or what exists in the world; these classifications help craft peoples' identities and aspirations (Bowker & Star, 1999, p. 4), while also informing our attitudes and actions. For designers, discussions of both ontology and phenomenology are important as they each provide a solid foundation on which to base our attitudes and behaviour towards things, combinations of living and nonliving, human and nonhuman. Alternative ontological systems have also been proposed as a way to overcome dualisms between object and subject (Cole, 2013, p. 106), nature and culture (Wagner, n.d.).

Ontological classification systems used by design practitioners and researchers vary widely, ranging from object-oriented ontology (Harman, 2018), vital materialism (Bennett, 2010), meshwork (Ingold, 2012), actor-network theory (Latour, 2005a), and process philosophy (Whitehead, 1960). Whitehead's (1960) philosophy has informed feminist philosophers such as Haraway (2016) and Stengers (2018). These scholars of ontology have articulated metaphorical ways to describe relationships between making and materials. Harman (2018) articulated "object-oriented ontology," (OOO) a theory for levelling out the ontological differences between the human, non-human, natural, cultural, real, or fictional, as these are all objects. Harman (2018) also discounts phenomenology, arguing that experience exists primarily of objects. There are seven principles for OOO. One of the more challenging is that objects are complete, discrete units and they never touch, which means that there is no exchange or interaction between objects as they are fixed and static. The objects are "being" and not "becoming." For a designer, this stance is conceptually quite challenging and problematic as it proposes materials that are inert, static and unresponsive, which is different from how we think of material and our relationships to the objects we make from them. Bryant (2016) proposes folding to overcome the OOO principle that real objects do not touch. For Bryant (2016), folds and folding are a continuous action so the becoming and being are indistinguishable – the origami of being. The fold is also a link between the field and thing with potential for a multiplicity of folds, folds underneath folds, which are coiled within folds radiating out. Whilst Bryant's (2016) origami of being is a beautiful descriptor of relations between objects, it seems like a poetic workaround to connect OOO to his experience of the world.

Actor-network theory (ANT) was developed by Latour (2005a) and others in the 1980s and proposes that the world is made up of different entities (actors) and linkages between these entities (networks). Agency of the entities is enacted through the relationships and networks between actors. Ingold (2008) later proposed a meshwork instead of ANT: meshwork describes an openness or porosity of entities, which adds further complexity to how these relationships could be understood.

> [Meshwork] is not a closed-in, self-contained object that is set over against other objects with which it may then be juxtaposed or conjoined. It is rather a bundle or tissue of strands, tightly drawn together here but trailing loose ends there, which tangle with other strands from other bundles. (Ingold, 2008, p. 211)

"Leaky things" is another way that Ingold (2012) describes the porosity of entities in meshwork. The deliberate use of the word "thing" is an intentional shift away from the subject/object divide (Brown, 2001), as a thing implies more agency and action than an object. Leaky captures the exchange of "living," where things take from their environment, consume, ingest, and also discharge. Things exist because they leak; this shifts the thinking from solid and defined material culture towards material ecologies.

New materialism argues for the agency of materials and the aliveness of matter, which changes the value placed on it and reshapes interactions with it. Bennett (2010) argues that new materialisms "inspire a greater sense of the extent to which all bodies are kin ... inextricably enmeshed in a dense network of relations" (p. 13).

New materialisms, OOO, and ANT are often grouped together along with speculative realism as all these ontologies promote "being or becoming" as primary, with other forms of philosophical enquiry being secondary. Boysen (2018, p. 225) and Cole (2013) crudely labelled these theories "flat ontologies." The term "flat" is used to highlight the non-hierarchical structure between humans and objects, but it also implies a loss of richness and complexity that is found in all these ontologies.

Feminist philosophers have also worked alongside and adjacent to new materialism and ANT; however, OOO prompted a reply – object-oriented feminism (OOF). OOF brings feminist thinking in the philosophy of things, namely politics, erotics, and ethics (Behar, 2016). OOF uses humour and can adopt multiple, and sometimes contradictory, perspectives. "Shifting focus from feminist subjects to feminist objects extends a classic tenet of feminism, the ethic of care, to promote sympathies and camaraderie with nonhuman neighbors" (Behar, 2016, p. 8).

New materialism perspectives are enriched by concepts from process philosophy, particularly from Whitehead's (1960) philosophy of organism. Organism is a metaphysical alternative to the notion of substance (Latour, 2005b). Organism is where objects momentarily "become" through a complex web of interactions and histories, but then fades away to inform and influence future manifestations. "Concrescence: the many become one and are increased by one" (p. 32) is the term and definition that Whitehead (1960) uses to describe this process. Organism is in stark contrast to substance, where objects endure and exist by themselves (which is the ontological standpoint of OOO). For Whitehead (1960), the philosophy of organism offers an adventure into the unknown as concrescence is an ongoing evolving process.

Process theory has been woven into designers' vocabulary with the term "material processuality" (Tonuk & Fisher, 2020), giving vocabulary to material qualities that shift. Similarly, Ingold (2012) picks up on the changing nature of material qualities and suggests we tell the materials' histories (p. 434). Telling a material's history positions the material not as an object but as a thing that reacts and responds to different environments.

The MAKRO standpoint weaves together many of these theoretical threads to recognise the agency and vitality of materials within a meshwork of relations that are in a constant process of becoming. MAKRO as a methodology is about adventure and creativity (Whitehead, 1967), storytelling, and wild open-ended kinship (Haraway, 2016). Stengers (2021), continuing James's (1940) call that "philosophy must keep the windows and doors open" (p. 100), contends that keeping the windows and doors open is an active ongoing process, which allows for imagination and curiosity to reside with us. MAKRO as a methodology offers a way for citizens to navigate climate breakdown in the Anthropocene by promoting kinship relations between designers and materials. Becoming kin with materials is a way of staying with the trouble of climate breakdown and to continue the ongoing working with kin to fashion a recuperation of earth.

Classifying a relationship formalises the type of relation, but it also brings expectations or rules for exchanges that are applied to that relation. Family relations have expectations of care, solidarity, support. Kinship can carry the same expectations of familial relations, but it can be applied to people who do not share the same genealogy. While kinship between humans is a common occurrence that can be seen in many cultures today, extending kinship to other species or indeed to materials is a radical step, although in Indigenous cultures there are long traditions of more-than-human kinship (Chao, 2018). Haraway (2016) calls on us to "make kin not babies" (p. 160), to embrace unstable definitions and the troubling murky waters of non-human kinship. Becoming in the world with kin allows us to enact new possibilities with matter and the material world. A relational ontology provides a theoretical way for kinship relations to be applied to intra-human relations.

Becoming kin starts with an encounter, exchange, or leak, and it leads to sympoesis.[2] Becoming kin also carries an expectation of care, responsibility, and learning "to live and die well" (Haraway, 2016, p. 140).

Extending Haraway's (2016) work, I also consider design materials in kinship relations. To put material kin in the context of designing for an uncertain future, we might ask what does living well and dying well look like for material kin? Living well requires a slowing down and opening up where we learn about and from each other while we cultivate and cohabitate. Dying well implies disassembling, composting, and ultimately regenerating.

In her book *Slow Science,* Stengers (2018) advocates for slowing down and opening up to questions, different contexts, and becoming sensitive again, sensitive to the frictions and hesitations that speed ignores. To care for our kin, we need to slow down, ask questions, and "know more" both contextually and critically about our kin, which then situates us and holds us accountable (van Dooren, 2014) so that we stay with the trouble. Caring for material kin also recognises material fragility and embraces repair and maintenance as a practice of care (Denis & Pontille, 2015).

MAKRO in Action

MAKRO work is done primarily in a design kitchen. The MAKRO kitchen uses kitchen appliances and recipes, and shares intergenerational knowledge. Using the kitchen as a site of experimentation builds upon MAKRO's foundations of feminist philosophers, environmental humanities, and slow science. The design kitchen is a meeting place that is neither workshop nor lab, where both designers and scientists, professionals and amateurs can come and collaborate. The kitchen can also be understood as a site of care. The book *Foodies* describes how making and sharing food is an act of caring (Johnston, 2015). Situating MAKRO research and the development of novel materials in the kitchen troubles both science and design and allows serendipity, embodied learning, and unexpected collaborations to take place. The kitchen as a site of experimentation also provides an intuitive food-based cooking vocabulary to help "stay with the trouble" as Haraway (2016) suggests. I draw on this lexicon and the kitchen as a metaphor in this section to wade through the murky waters of material kin and MAKRO.

The MAKRO method requires a pantry. This is well-stocked, as it has been accumulating ingredients for quite a few years now. The ingredients in the pantry are either common food ingredients, food grade chemicals, or dried waste biomass. The table below shows the variety of ingredients in the MAKRO pantry grouped into ingredient types.

Water soluble binders	Methyl cellulose, hydroxypropyl cellulose, carboxymethyl cellulose, hydroxypropyl methyl cellulose, hydroxyethyl cellulose, xanthan gum, locust bean gum, gum arabic, pectin, guar gum, modified guar gum, agar, sodium alginate, carrageenan (kappa), amphoteric starch, cationic starch, modified starch, tapioca starch
Food industry chemicals	Vinegar, glucono delta lactone, alum, sodium chloride, calcium chloride, bicarb soda, tannic acid, calcium lactate, cream of tartar, baking powder
Household chemicals	Urea, sodium silicate, borax, soda ash
Plasticisers	Glycerin
Protein additives	Gelatin, Transgluatminase, Gluten, Sodium Caseinate, Albumen
Stabilisers	Microcrystalline Cellulose, Microfibrillated Cellulose
Surfactants	Sodium lauryl sulfate, mono and diglycerides, soy lecithin powder
Waste biomass	Coffee grounds, paper pulp, hemp fibre, sawdust, wool fibre, egg shells, oyster shells
Wax and wax additives	Beeswax, stearic acid, magnesium stearate

Table 1. MAKRO pantry ingredients grouped by type.

Together, the ingredients in the MAKRO pantry and I started to do some initial experimentation using recipes from various do-it-yourself biomaterial cookbooks and resources.[3] Current recipes I use now rely on the knowledge bank from previous tests along with the addition of academic material science papers and industry investigations as well input from polymer chemists. The initial experimentation generated tacit knowledge of the ingredient qualities and uncovered synergies between ingredients. An example of a synergy between ingredients can be found with locus bean gum and agar; combining the two ingredients enhances the ingredient qualities well beyond the properties of each singular ingredient. This experimentation helped to set up the kitchen and other environmental conditions which best suited the samples. The preliminary exploration was undertaken before adding another key ingredient – air.

MAKRO Foam

"Material with pockets of air" is the definition I have developed of a foam-type material. The pockets of air can either be sealed off or the pockets can interlink with other pockets to form a web-like sponge structure. Air can be mixed with material to make foam in many ways, from whipping egg whites (mechanical foaming), to raising agents like baking powder (chemical foaming), to aerosol whipped cream (pressurised foaming), or to a pocketed surface texture like a knitted scarf (engineered foam).

Mechanical foaming techniques were selected as a starting point for investigation as it is an accessible entry point for foam discoveries. Verbs that describe this process include "whip," "beat," "shake," "agitate," and "steam," while the tools used to create mechanical foam range from "fork" to "whisk," "paint stirrer," "milkshake maker," "food processor," and "blender." Mechanical foam requires the material to be aerated while it is liquid and then dried to a solid state.

Cellulose was also chosen as the primary ingredient to undertake mechanical foam testing as it is insoluble, there are various forms of cellulose, and it has the properties of either a binder or filler. Cellulose can also work in different environments with a range of temperatures and pH levels while also having a high level of resistance to mould and other microbes.

I undertook extensive testing of cellulose foam materials, which allowed me to develop a detailed understanding of different foam properties as well as mechanical foaming processes. A selection of the foamed cellulose tests can be seen in Figure 1. The testing led to an ongoing intimate knowledge of the materials, and in some instances, required me to alter my design practice. This series of encounters (tests) was instrumental to forming kinship relations with the foam materials. While I engaged the materials to promote unstable relations with air, the materials answered, instructing me to work with them, forcing me to rethink the processes and methods of working together. Exchanges of this nature are part of becoming kin with material.

Figure 1. Cellulose foam tests.

The material has its own intelligence and its own agency, and it asserts this during the testing and making, showing the agency of materials and the aliveness of matter described by Bennett (2010). The exchanges that took place were subtle but insistent, requiring me to open my way of working and respond to the material. For example, I found that the liquid viscosity of the mixture to be foamed impacted the density of the foam. If a soft billowy type of foam was required, the mixture needed to be quite runny but still sticky (somewhere between the consistency of an egg white and mayonnaise). If the mixture was too runny, the foam would collapse before it dried out, and if it was too thick, it was hard to incorporate the air, or the air would form one big pocket rather than lots of small pockets.

Through making kin with the material, I learnt that low temperatures with low humidity for a long time produced the best results for drying the foam. If the time that the material took to dry was too long, the foam would collapse, and if the heat was too aggressive, it would cause cracking, crumbling, and deflation. Shrinkage of the material and warping also would occur as water left the material, and upscaling the recipes amplified the drying times and foam deflation.

Tests were undertaken to foam mixtures with less water to minimise shrinkage and drying time, but the foams lost their integrity and became a solid material. A solution for how to decrease the water content of the mixture while still maintaining foam integrity was to make a cellulose Eton mess.[4] The cellulose Eton mess is made by combining small pieces of dried foam and short cellulose fibres to a whipped cellulose mixture. The types of dried foam can be varied along with ratios of foam to whipped mixture to make material kin with differing qualities. The Eton process reduces the overall amount of water, speeds up the drying time, and minimises shrinkage and is used to develop the critical design piece.

The MAKRO Lifejacket

The lifejacket I have designed using a MAKRO approach and with the intention of making kin with the foam material is an experiment in transforming foam into a wearable flotation device. It can function as a safety aid to provide buoyancy in an emergency, be worn during a particular activity, or be carried in anticipation of rapidly rising waters. The lifejacket was designed using the MAKRO methodology in response to the weather conditions caused by the Anthropocene and consumption habits that have led to climate breakdown. The lifejacket has been situated in this context, so, while it utilises a biobased alternative to ethylene-vinyl acetate[5] (EVA) foam lifejackets, the goal is not to promote this lifejacket as drop-in replacement for EVA, but to think through solutions for material buoyancy – a crucial property in the context of rising waters

This piece has been modelled to fit within the level 100 lifejacket class, using the Australian standard AS4758 (NRMA, 2021). This means that the lifejacket has a neck brace that keeps the head out of water and provides 100 Newtons of buoyancy. There are more comfortable life jackets that fit closer to the body (level 50) that are designed to maximise the body's movement, but they do not provide any neck support. This lifejacket is designed to be disassembled and packed away as the neck balloon separates from the buoyancy board. Placing the emphasis on storage when not in use implies that the lifejacket is designed to be worn as an emergency item rather than for recreational fishing or sporting use.

Figure 2. MAKRO lifejacket sketch.

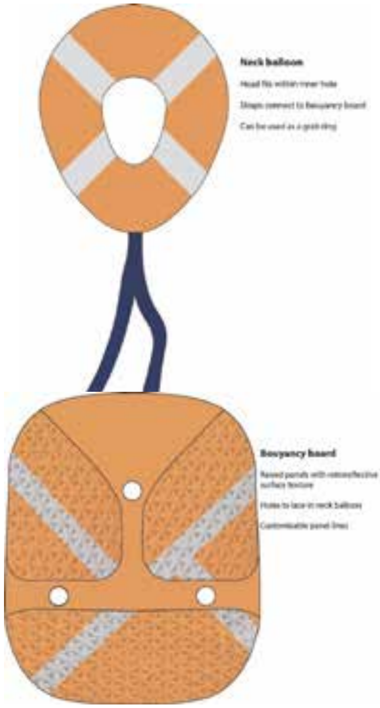

Figure 3. MAKRO lifejacket components.

The MAKRO lifejacket uses a very lightweight foam made from methyl cellulose (MC) and dried brewer's spent grain. MC has a unique property of forming a gel in high temperatures, which allows the moisture to be taken out of the material quickly without deflating the foam too much. The brewer's spent grain is a waste byproduct from brewing beer. In the brewing process, the grain (usually barley) is cracked and steeped in water to extract the soluble sugars from the grain. Once most of the sugar has been extracted, the soggy spent grain is now a waste by-product. The spent grain is quite high in cellulose and hemicellulose with some residual sugars. Brewer's spent grain is a lightweight filler and adds body to the foam without adding too much weight.

A lifejacket should be able to resist and absorb knocks and bumps that might occur; to this end, a strong rigid foam (which looks similar to rye bread) has been developed as a casing for the softer, more buoyant foam of the MAKRO lifejacket. The "rye bread" foam uses carboxymethyl cellulose (CMC), a starch binder, and three different kinds of cellulose. Micro fibrillated cellulose gives it stability as a foam while it is drying. Sawdust and recycled paper pulp bulk out the material and bind strongly with the CMC and starch, while the hemp fibre gives the foam extra reinforcement.

Figure 4. Rigid foam (as a liquid).

Unlike most lifejackets available in Australia, there is no fabric covering the foam of the MAKRO lifejacket. Rather, the foam has been coated with casein waterproof glue, which provides protection from the water. The MAKRO lifejacket has been divided into twelve sections and sealed, so if a leak occurs it can be contained to its section and not jeopardise the functionality of the lifejacket.

Bright yellow is the most common colour of lifejackets available worldwide. The casein coating of the MAKRO lifejacket has been coloured with a vibrant yellow pigment made from turmeric, bought in the spice aisle of a supermarket. The casein coating also gives a gloss shine coating, making the colour punchier.

Retroreflection is particularly useful for search and rescue situations. Retroreflection reflects light from the rescue party back to the source. Retroreflection is produced by the geometry of the interior corner of a cube. The three surfaces of the cube bounce the light from one surface to the next before it is reflected back in the direction of the original beam. To create a space-efficient surface texture, the corner of a cube can be cut off, embedded into the surface, and repeated so that there are many "internal cube corners" on the surface of the object. This surface texture, shown in Figure 5, has been embedded into the surface of the lifejacket.

Figure 5. Multiple internal cube corners surface texture prototype.

Conclusion

In this paper I have introduced MAKRO, a methodology for making material kin. To do so, I began by outlining the conditions of the Anthropocene that have motivated this work: the intense fires and floods on the east coast of Australia – a manifestation of climate breakdown – along with unsustainable resource consumption. Shifting to a regenerative material system – which includes working closely with biobased materials – is then proposed as a way to fashion a recuperation of earth. I then offered a theoretical underpinning to explain how MAKRO was developed, including the threads of new materialism, feminist phenomenology, ANT, and meshwork, and incorporating themes of kinshipand care. Finally, I presented a design experiment applying the MAKRO methodology to the fabrication of the MAKRO lifejacket. This work is ongoing and iterative. The nature of working in a design kitchen with an emerging methodology means there are as many questions raised as there are "finished" products. Some of these questions are: as designers, how can we work with and be responsive to biobased materials? How do we have to change our assumptions on what materials can do and our practice working with them? Together with material kin, how can we foster a culture of care and regeneration? MAKRO offers a guide for developing material answers to these questions and others.

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[1] Biobased materials are materials that are cultivated and sourced from living and growing systems.
[2] "Sympoesis [making-with] is a carrier bag for ongoingness, a yoke for becoming with, for staying with the trouble of inheriting the damages and achievements of colonial and postcolonial natural cultural histories in telling the tale of still possible recuperation" (Haraway, 2016, p. 125).
[3] Recipes such as: *CHEMARTS cookbook* (P. Kääriäinen, N. Riutta, L. Tervinen, T. Vuorinen & Aalto University, 2020), Materiom website (Materiom, n.d.),
https://issuu.com/nat_arc/docs/bioplastic_cook_book_3
https://issuu.com/miriamribul/docs/miriam_ribul_recipes_for_material_a
https://issuu.com/johanviladrich/docs/bioplastic
https://issuu.com/juliettepepin/docs/bookletbioplastic
[4] Eton mess is a British dessert made by combining broken pieces of meringue, fruit, and cream.
[5] Ethylene-vinyl acetate is a common synthetic foam; yoga mats are commonly made with EVA foam.