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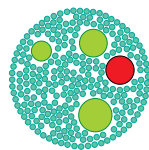
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Patent depositing of algal strains

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ABSTRACT

Algae and protozoa underpin biological productivity from the poles to the equator, produce most of the world's oxygen and a myriad of valuable commodities such as pigments, oils, antioxidants and proteins. Algae are the subject of many thousands of patent applications in varied fields from bioremediation to nutraceuticals. The patenting of microorganisms including algae was made easier and more secure with the signing of the Budapest Treaty and the creation of International Depository Authorities, such as the Culture Collection of Algae and Protozoa (CCAP), which is a Biological Resource Centre and is a trusted global leader in the provision of algal and protozoan cultures, knowledge and associated services. There are challenges ahead in incorporating Intellectual Property laws with Access and Benefit Sharing regulations such as the Nagoya Protocol but tools are being developed to enable progress.

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Introduction

Although microalgae and macroalgae account for only 1–2% of total global biomass, these organisms may be responsible for no less than 30–60% of the total global annual fixation of carbon on earth (Sakshaug et al., 1997). Protists (microalgae and protozoa) make up the vast bulk of eukaryote diversity, with lineages across most of the eukaryotic tree of life. Microalgae and cyanobacteria are ubiquitous, found in almost every ecosystem. There are species that can thrive in extreme environments – high salinity, high CO₂, extremes of temperature, heavy metal pollution and radioactivity (McGraw et al., 2018; Varshney, Mikulic, Vonshak, Beardall, & Wangikar, 2015). Algae and cyanobacteria produce a range of molecules that can be important for biotechnology, aquaculture, biofuels and pharmaceutical industries, which include fatty acids, pigments, proteins, antioxidants and polysaccharides. Some of these molecules are specifically produced to help the cells survive under extreme conditions, for example the microalga *Haematococcus* produces the red pigment astaxanthin under stress conditions, the pigment is believed to protect the resting cysts against excess light (Varshney et al., 2015). Advances in genetic engineering and cultivation methods can enhance productivity and improve the potential of microorganisms as a source of renewable bioproducts (Khan, Shin, & Kim, 2018). As well as the goal of tackling the global challenges of food supplies, a growing population and demand for resources, successful biotechnology-based

activities also need to be profitable, achieved by reducing production and downstream costs through increasing productivity or efficiency. This is where many patent applications fit in.

Patenting microorganisms

Microorganisms and processes involving microorganisms have been the subject of patents and patent applications for over 200 years. Many of the oldest such patents covered baking and brewing yeasts and one of the first is patent GB178701625, obtained in 1787 by Blunt: “A new-invented composition to be used as yeast”, describing the preparation of a dough using mashed potatoes, honey and common yeast (Gélinas, 2010). In July 1873, microbiologist Louis Pasteur patented his improved yeast making method at the French Patent Office, patent number FR 98476.

A recognized problem with patenting an invention that requires a specific strain of microorganism is reproducibility, as disclosure of the invention, typically by means of a written description, is a requirement for the granting of patents. There is potential difficulty in relying on a written disclosure when a microorganism is involved. A strain may be genetically modified, e.g. patent WO2917163144 in which a genetically modified *Chlorella sorokiniana* strain has increased biomass, reduced clumping and increased stress tolerance to UV light and high light intensity compared with the wild-type *Chlorella sorokiniana*. Even if a strain is

isolated from a common source, e.g. soil at a particular site, there is no guarantee that the same species collected from the same site at a later date, or even the same date, will exhibit the same characteristics as there can be large intraspecific variation (Burkholder & Glibert, 2006). One way to overcome these issues is to deposit a sample of the microorganism in a culture collection, where there are expert staff and specialized equipment for the preservation and maintenance of particular types of microorganism. The first two known recorded deposits for patent purposes were bacteria, *Streptomyces* strains deposited with the American Type Culture Collection (ATCC) and Agricultural Research Service Culture Collection, respectively, both located in the US (U.S. Congress, 1989).

Depositing a microorganism in a facility in the country in which the patent is to be applied for is one thing, but there is a further question of what to do if the patent protection is sought in several or additional countries. It would be costly and inefficient to deposit a sample in each of these countries – and not all countries have the capacity to store the full range of potential microorganisms, from viruses, bacteria and fungi to algae and protozoa.

The Budapest Treaty (or, to give its full name, The Budapest Treaty on the International Recognition of the Deposit of Microorganisms for the Purposes of Patent Procedure) is an international treaty signed in Budapest, Hungary, on 28 April 1977. It is administered by the World Intellectual Property Organisation (WIPO). The treaty states that the deposit of a microorganism with any “International Depositary Authority” (IDA) will be recognized in all countries party to the treaty and will allow patents to be applied for in other countries with no need for further deposit. The term “microorganism” is not defined in the treaty leaving it open to interpretation. There are IDAs that accept tissue cultures, DNA and plasmids, for example, as well as microorganism cultures.

Any culture collection or facility capable of storing microorganisms can become an IDA provided that it has been formally nominated by the Contracting State on whose territory it is located, and that the Contracting State has furnished solemn assurances that the collection complies, and will continue to comply with the requirements of the Treaty and the Regulations. An IDA must maintain secrecy about the deposited resources but must furnish (supply) samples of deposited microorganisms to entitled third parties on application. The depositor has a right to a sample at any time and may authorize any third party to request a sample. In addition, any industrial property office to which the treaty applies may ask for a sample for purposes of

patent procedure. An IDA must be capable of storing the deposit, with all the care necessary to keep it viable and uncontaminated, for at least 5 years after the last request for a sample, and for a minimum period of 30 years after the date of deposit. WIPO makes available a Guide to the Deposit of Microorganisms under the Budapest Treaty on their website www.wipo.int/budapest. The formation of IDAs establishes a uniform system of deposit, recognition and supply of samples, giving security to depositors.

The Budapest Treaty came into force on 9 August 1980, and as of July 2019, 82 countries were party, with the most recent member being Antigua and Barbuda, where the Treaty came into force in June 2019 (WIPO, 2019b). There are now 47 IDAs in 26 countries across the globe, the latest being the CM-CNRG collection in Mexico, which acquired IDA status in August 2015 (Table 1). The UK signed the Budapest Treaty in 1977, one of the original 13 signatories, and currently has 7 IDAs, including the Culture Collection of Algae and Protozoa (CCAP) and the National Collection of Industrial, Food and Marine Bacteria (NCIMB), both acquiring IDA status in 1982.

IDAs can charge a fee for storing a microorganism in accordance with the Budapest Treaty and also for supplying samples (other than to an Industrial Property Office) and providing documents on request such as scientific description or viability statements. This is a vital source of income for sustaining collections that are not always in receipt of public or private funding or able to generate significant commercial income. The initial storage fee must be a one-off charge, and so covers the whole duration of storage. As this is a minimum period of 30 years, the maintenance and storage costs, even if the microorganism is kept in an inactive state, are not insignificant.

CCAP – the Culture Collection of Algae and Protozoa

CCAP is a Biological Resource Centre (BRC). The OECD describes BRCs as follows: “Biological Resource Centres” are essential for Research and Development in the life sciences, for advances in the quality of the environment, agriculture, and human health, and for the commercial development of biotechnology. Their many crucial roles include: “... Repositories of biological resources for protection of intellectual property” (OECD, 2001). CCAP functions as the national service collection of algae and protozoa in the UK, maintaining, characterizing and distributing living cultures of marine and freshwater algae, cyanobacteria, protozoa, algal

Table 1. International depository authorities under Article 7 of the Budapest Treaty, status on 23 July 2018. Bold type indicates IDAs that accept algae and/or protozoa (WIPO, 2019a).

Institution	Country	Date status acquired
Advanced Biotechnology Center (ABC)	Italy	29 February 1996
Agricultural Research Service Culture Collection (NRRL)	USA	31 January 1981
All-Russian Collection of Industrial Microorganisms (VKPM)	Russian Federation	31 August 1987
American Type Culture Collection (ATCC)	USA	31 January 1981
Banco Español de Algas (BEA)	Spain	28 October 2005
Belgian Coordinated Collections of Microorganisms (BCCM™)	Belgium	1 March 1992
CABI Bioscience, UK Centre (IMI)	United Kingdom	31 March 1983
China Center for Type Culture Collection (CCTCC)	China	1 July 1995
China General Microbiological Culture Collection Center (CGMCC)	China	1 July 1995
Colección Chilena de Recursos Genéticos Microbianos (ChRGM)	Chile	26 March 2012
Colección de Microorganismos del Centro Nacional de Recursos Genéticos (CM-CNRG)	Mexico	25 August 2015
Colección Española de Cultivos Tipo (CECT)	Spain	31 May 1992
Collection nationale de cultures de micro-organismes (CNCM)	France	31 August 1984
Collection of Industrial Yeasts DBVPG	Italy	31 January 1997
Culture Collection of Algae and Protozoa (CCAP)	United Kingdom	30 September 1982
Culture Collection of Switzerland AG (CCOS)	Switzerland	16 January 2017
Culture Collection of Yeasts (CCY)	Slovakia	31 August 1992
Czech Collection of Microorganisms (CCM)	Czech Republic	31 August 1992
European Collection of Cell Cultures (ECACC)	United Kingdom	30 September 1984
Guangdong Microbial Culture Collection Center (GDMCC)	China	1 January 2016
IAFB Collection of Industrial Microorganisms	Poland	31 December 2000
International Depository Authority of Canada (IDAC)	Canada	30 November 1998
International Patent Organism Depository (IPOD), National Institute of Technology and Evaluation (NITE)	Japan	1 May 1981
Istituto Zooprofilattico Sperimentale della Lombardia e dell'Emilia Romagna «Bruno Ubertini» (IZSLER)	Italy	9 February 2015
Korean Agricultural Culture Collection (KACC)	Republic of Korea	1 May 2015
Korean Cell Line Research Foundation (KCLRF)	Republic of Korea	31 August 1993
Korean Collection for Type Cultures (KCTC)	Republic of Korea	30 June 1990
Korean Culture Center of Microorganisms (KCCM)	Republic of Korea	30 June 1990
Lady Mary Fairfax Cellbank Australia (CBA)	Australia	22 February 2010
Leibniz-Institut DSMZ – Deutsche Sammlung von Mikroorganismen und Zellkulturen GmbH (DSMZ)	Germany	1 October 1981
Microbial Culture Collection (MCC)	India	9 April 2011
Microbial Strain Collection of Latvia (MSCL)	Latvia	31 May 1997
Microbial Type Culture Collection and Gene Bank (MTCC)	India	4 October 2002
Moroccan Coordinated Collections of Microorganisms (CCMM)	Morocco	20 February 2018
National Bank for Industrial Microorganisms and Cell Cultures (NBIMCC)	Bulgaria	31 October 1987
National Collection of Agricultural and Industrial Microorganisms (NCAIM)	Hungary	1 June 1986
National Collection of Type Cultures (NCTC)	United Kingdom	31 August 1982
National Collection of Yeast Cultures (NCYC)	United Kingdom	31 January 1982
National Collections of Industrial, Food and Marine Bacteria (NCIMB)	United Kingdom	31 March 1982
National Institute for Biological Standards and Controls (NIBSC)	United Kingdom	16 December 2004
National Institute of Technology and Evaluation, Patent Microorganisms Depository (NPMDD)	Japan	1 April 2004
National Measurement Institute (NMI)	Australia	30 September 1988
Polish Collection of Microorganisms (PCM)	Poland	31 December 2000
Provasoli-Guillard National Center for Marine Algae and Microbiota (NCMA)	USA	26 April 2013
Russian Collection of Microorganisms (VKM)	Russian Federation	31 August 1987
VTT Culture Collection (VTCC)	Finland	25 August 2010
Westerdijk Fungal Biodiversity Institute (CBS)	Netherlands	1 October 1981

pathogens and related organisms. CCAP also provides taxonomic, technical and educational expertise, services and resources for culture isolation and curation to scientists, educators, researchers and businesses worldwide. As well as being an IDA, CCAP also accepts confidential deposits for safe-keeping, and standard deposits that are entered into its public catalogue. The collection is linked with other service collections worldwide via the European Culture Collections' Organisation (ECCO) and the World Federation for Culture Collections (WFCC).

The foundations of the CCAP were laid by Professor Ernst Georg Pringsheim, who with his collaborators, Victor Czurda and Felix Mainx, isolated a number of cultures at the Botanical Institute

of the German University of Prague in the 1920s (Day et al., 2004). Pringsheim and his cultures moved to England where the collection was expanded and eventually taken over by E.A. George for Cambridge University in 1947. In 1970, these cultures formed the basis of the Culture Centre of Algae and Protozoa at Cambridge. In 1986, the collection moved to the Freshwater Biological Association at Windermere (freshwater strains) and the Scottish Marine Biological Association (SMBA) at the Dunstaffnage Marine Laboratory (DML) by Oban (marine strains). The two sections were reunited in 2004 in the new Scottish Association for Marine Science laboratory on the DML site. CCAP receives its major funding from the Natural Environment

Research Council (NERC), part of UK Research and Innovation.

CCAP accepted its first patent deposit in 1994, from a University in Spain. The deposit is cited in Spanish patent ES2088366 “Marine microalga and its use in agriculture and in obtaining polyunsaturated fatty acids”. The summary describes a strain of the marine microalga *Isochrysis galbana* capable of producing high quantities of polyunsaturated fatty acids, especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). The strain has also been cited in at least three research papers published between 1996 and 1998 in the Journal of Biotechnology, Enzyme and Microbial Technology, and Applied Microbiology and Biotechnology. This is of note as in the UK, academics are often under pressure to publish their work in the form of scientific papers rather than file patent applications (Smart, 2018), whereas in practice it is possible to patent – giving the legal right to prevent others gaining financially from the research – and to publish in journals. The same article notes that amongst the 4% of total patent applications filed at the European Patent Office (EPO) in 2016 in the field of biotechnology, none of the top applicants were UK universities.

CCAP accepts for patent deposit freshwater and terrestrial algae and free-living protozoa, and marine algae other than large seaweeds. There are in total 11 IDAs that accept algae or/and protozoa (Table 1), 3 are within Europe – CCAP, Banco Español de Algas (BEA) in Spain, accepting a similar range of organisms to CCAP, and Culture Collection of Switzerland AG (CCOS) which accepts a wide range of microorganism types. BEA receives an average of 4.5 deposits per year, compared to CCAP with an average of 6. As CCOS only became an IDA in 2017, it had only 4 deposits listed in the latest WIPO statistics (WIPO, 2018a).

As of October 2019, CCAP has 151 patent deposit strains. One hundred and forty-one of these are cryopreserved in liquid nitrogen, another two are freeze-dried. These long-term, stable storage methods are preferred over maintenance by serial subculture as they minimize the risk of genetic change over time. There are few long-term studies, but for some algal taxa, serial transfer can result in the loss of attributes such as production of toxins or commercially relevant metabolites (Day & Fleck, 2015). Holding microalgal cultures in an inactive state also allows for several replicate and/or back up samples to be held and reduces the opportunities for human errors such as mis-labelling or contamination during transfer. It is possible to cryopreserve many algal and protozoan taxa, and CCAP also holds one algal consortium – a mixture of several microalgae plus bacteria – as a patent deposit. Silkina, Nelson,

Bayliss, Pooley, and Day (2017) described the procedure involved and reported that the activity (bioremediation of effluent from an anaerobic digestion plant) of the consortium after 3 months in liquid nitrogen was not significantly different to a non-cryopreserved control. The use of algal/bacteria consortia may be a growth area in biomanufacturing, co-cultures have shown improvements in yields of biomass, lipids and high-value products compared to monocultures, and may also be more resilient to contamination (Padmaperuma, Kapoore, Gilmour, & Vaidyanathan, 2018). Culture collections are ideally placed to deal with these challenges and developments in biotechnology.

CCAP's deposits have been received from 41 different depositors, from 17 countries. Most of these countries (10) are within the EU, another four countries are developing economies (United Nations, 2019). Forty-seven per cent of depositors are academic or government funded (this covers 35% of the CCAP patent strains). Five depositors are from within the UK, three of these are academic (four strains), one commercial (two strains) and three strains are from individuals. The number of deposits for patent purposes received by CCAP varies from year to year, but there has been a general and significant increase from around 2008 onwards (Fig 1), this matches the general trend as described later.

The majority of CCAP's patent deposit holdings are chlorophytes (40%), with lower but significant numbers of Cyanobacteria (28%), thraustochytrids (11%) and diatoms (7%). The most represented genus is *Chlorella* (13%). Of the genera noted as being “popular” in respect of patent applications, we have 20 deposits of *Chlorella*, 5 *Haematococcus*, 5 *Dunaliella* and 2 *Spirulina/Arthrospira*.

At least 77 patents or patent applications cite strains that are deposited with CCAP under the Budapest Treaty. These cover agriculture and fatty acid production, use as a pesticide, production of rare monosaccharides, biofuels, photosynthetic hydrogen production, carotenoid or lutein production, biomass, cosmetics, and an antimalarial agent. There are also patent documents that cite strains that are available in CCAP's public catalogue.

Patenting activity in the microalgal field

According to one market research forecast summary, the algal products market was estimated at 3.98 billion USD in 2018 and is projected to reach 5.17 billion USD by 2023. This growth is largely attributed to increased consumer awareness of the health benefits of algae-based products, plant-based proteins for the food

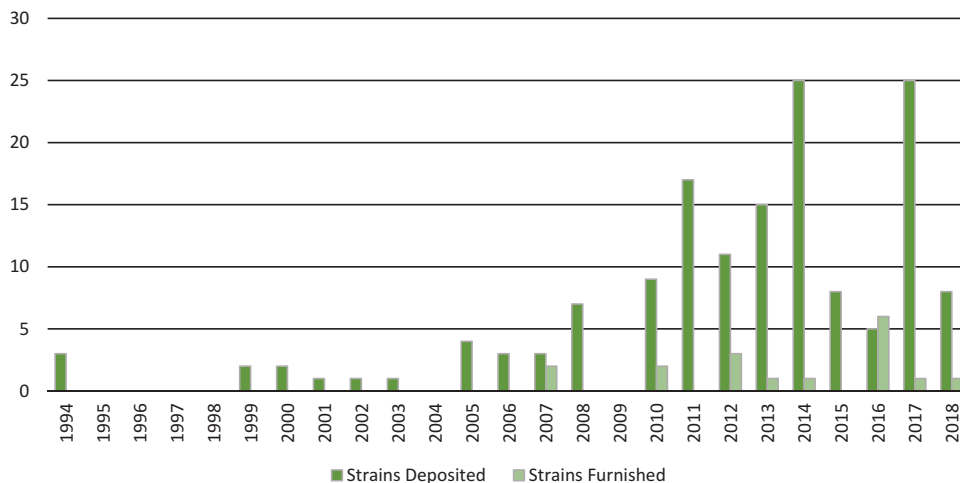


Figure 1. CCAP: strains deposited and supplied under the Budapest Treaty.

industry, and pharmaceuticals, with the highest growth rate in the Asia Pacific region (Markets and Markets, 2018).

WIPO generates and makes available statistics and reports on a huge variety of criteria. One of these datasets has been compiled into a patent landscape report on microalgae-related technology, which lists patent applications between 1995 and 2015 that reference microalgae (WIPO, 2016a). This dataset totals over 11,000 patent applications and contains a wealth of information on the geography (offices of first and additional filings), applicants, major strains, processes and products.

From this report, it is clear that the vast majority of patent activity in microalgae is in Asia (75%, with more than half of these filings coming from China), followed by the US (13%) and then Europe (9.8%). As noted above, Asia is forecast to continue this trend. For the UK, numbers of microalgae-related patents per 5-year period grew over the 20 years covered by the report, although this totals only 72 publications.

Over the 20-year period covered by the data, there has been a consistent increase in microalgae-related patent publications, year on year, from 126 in 1995 to 1349 in 2013, the last year with complete data (WIPO, 2016a; Fig 1). Over this period, 38% of applicants were academic or government research institutions, 46% industrial. There are collaborations between academic and industrial partners, but these account for only 2.1% of applications.

Many patent applications are utilizing the same species, for the same purposes. Those strains mainly developed for biofuels have tended not to be exploited yet for other products. The most popular genera are listed below, and this is reflected by CCAP's patent deposits – we have deposits of all but two of these genera.

- *Chlorella* for biofuel production.
- *Spirulina* for protein production and protein animal feed, but also for the production of pigments, in particular phycocyanin (a phycobiliprotein).
- *Tetraselmis*, *Botryococcus*, *Scenedesmus*, *Nannochloropsis*, *Anabaena*, *Synechococcus*, *Synechocystis* for biofuels.
- *Chlamydomonas* for biofuels, especially biohydrogen.
- *Cryptocodinium*, *Schyzochytrium*, *Thraustochytrium* and *Aurantiochytrium* for the production of lipids.
- *Euglena* for the production of polysaccharides (including paramylon, a molecule specific to this strain).
- *Dunaliella* and *Haematococcus* especially for pigment, beta-carotene and astaxanthin, respectively.

The patent documents analysed for the report cover inventions concerning cultivation method (autotrophy, mixotrophy, heterotrophy), farming systems, harvesting and extraction of compounds. Activity in many of these areas boomed when biofuel research first took off, the industrial cultivation of microalgae for the biofuel industry increased dramatically over the last couple of decades (Khan et al., 2018). Although biofuel is the product category with the most patents, its growth has waned over the last several years as there are challenges still to overcome – high costs, limits on microalgal biomass production and processing/harvesting efficiency. Since 2010, there has been growth in newer areas – proteins and polysaccharides, in response to new challenges in the food and animal feed markets, and cosmetics (WIPO, 2016a; Fig. 38).

For animal feed and nutrition, the challenge is to find alternatives to proteins of animal origin, to improve the quality of eggs, meat and milk, and increase animal growth. Pigments, e.g. carotenoids, are of interest as

they can provide natural colouring, and are of similar interest in aquaculture. In the aquaculture sector (which includes fish, shellfish, shrimp and seaweed), the aim is to capitalize on the active ingredients produced naturally by the microalgae by optimizing cultivation conditions.

Use of microalgal products in cosmetics is a growing area, largely utilizing pigments and proteins for skincare products. Microalgae are used as moisturizing and thickening agents, and have potential uses in anti-ageing, UV protection and pigmenting products (Wang, Chen, Huynh, & Chang, 2015).

Microalgae patents under the category of energy aim to increase lipid and strain productivity for the production of biofuels and develop methods of extracting lipids efficiently. One challenge is to solve the most notable disadvantage of microalgae – their much longer cell division cycle compared to bacteria.

Use of algae for human nutrition, e.g. as a food protein source, is already well developed in Asia and is growing elsewhere. Pigments are also of interest for human nutrition, e.g. beta carotene, astaxanthin, lutein and fucoxanthin. There are patent publications describing microalgae as new sources of omega 3 and 6 and phytosterols (WIPO, 2016a). The UK-based biotechnology company Algenuity have a patent pending on a range of food/cosmetic colours obtained through fermentation of *Chlorella* strains – with the advantages of being non-genetically modified, natural, and containing vitamins, carotenoids, antioxidants and micronutrients (Algenuity, 2019).

In the therapeutic area, there is patenting activity around the use of microalgal-derived DHA (docosahexaenoic acid – an omega-3 fatty acid) to treat Alzheimer's disease, and lutein (a type of carotenoid) to treat eye disease (WIPO, 2016a).

A possibly emerging field is biomaterials, and by 2015, there were a few hundred patent documents in this field. These cover a range of applications including the use of biopolymers from cyanobacteria to produce plastics, development of biomaterials to clean contaminated environments, medical use of photosynthetic scaffolds in tissue engineering and use of diatom biomaterial as catalysts to facilitate hydrogen storage (WIPO, 2016a).

Access and benefit sharing

The Nagoya Protocol (Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from Their Utilization to the Convention on Biological Diversity) is a supplementary agreement to the UN's Convention on Biological

Diversity, adopted in 2010 and coming into force on the 12 October 2014. It recognizes the rights of countries to regulate access and utilization of their genetic resources and associated traditional knowledge through national legislation. Countries can negotiate the sharing of any benefits arising from the research and development and/or commercialization of these resources, whether monetary or otherwise, such as training or other collaboration. This benefit sharing has the potential to positively influence biodiversity and its sustainable use. One potential benefit shared with an originating country can be joint ownership of patents or other relevant IP rights (WIPO, 2018b).

WIPO Member States are considering whether, and to what extent, the IP system should be used to support the implementation of obligations related to the Nagoya Protocol and other similar access and benefit sharing systems (WIPO, 2016b). Guidelines and advice need to be in place, as although some research projects based on microorganisms may have as their intention, the discovery of a patentable invention and the subsequent commercial development of that invention, and so advice can be sought at the very beginning of the process, other, particularly academic, projects may inadvertently or unexpectedly result in the conception of a patent.

The Nagoya Protocol was discussed briefly at the Second WIPO Meeting of Representatives of International Depository Authorities, held at the CM-CNRG in Mexico in September 2018. Compliance with the Nagoya Protocol is not a requirement that IDAs should check in the frame of the Budapest Treaty, as WIPO considers this to be the task of the patent office with which the patent has been filed. It was confirmed that an IDA cannot refuse a deposit based on it being in scope of the Nagoya Protocol, or for lack of relevant information, assuming that the strain meets all the other acceptance criteria set by the IDA. Storage of the microorganism is not in the scope of the Nagoya Protocol, however once a strain reaches the end of its deposit period, it cannot be supplied without relevant information to determine whether or not it is in the scope of the Protocol. As patent deposits must be held for a minimum of 30 years, and the date after which genetic resources may be in the scope of the Nagoya Protocol is 12 October 2014 (the date the protocol entered into force), this may not be a major issue until 2044, however there are already several thousand deposits potentially in scope. In 2018, there were 6249 deposits across the 47 IDAs (WIPO, 2018a). At the time of writing, CCAP has 56 deposits received since the Nagoya Protocol came into force. IDAs propose to change the application forms so that the minimum information, according to

the MIRRI best practice guidelines (Verkley, Martin, & Smith, 2016), can be completed by the depositor. This information can then be passed on to any person receiving a sample. It will include the country of origin of the sample, the date of collection, and, where the sample is in the scope of the Nagoya Protocol, proof of legal access, agreed terms of use and any Access and Benefit Sharing agreement.

In conclusion, microalgal biotechnology has experienced strong growth over recent years and algae and protozoa have a pivotal role to play in the future low-carbon economy, also helping to meet grand challenges and UN development goals such as climate action, life below the water, good health and well-being, and food safety. Patenting is a tool that is widely used in the sector. The importance of patent protection is vital, and the patent system provides fair protection for inventors, whilst fuelling innovation by providing public disclosure of inventions. It is possible to both patent an invention involving a microorganism and publish scientific papers, fulfilling the obligations of academic researchers. IDAs such as CCAP are a vital resource for enabling the patenting of inventions that utilize specific or genetically modified microalgae, and the income from holding patent deposits is essential to help sustain culture collections. CCAP is a living treasure to be curated for and used by the scientific community in the UK and around the globe.

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Author contribution

RJ Saxon drafted the manuscript; C Rad-Menéndez and CN Campbell critically revised the manuscript and all gave final approval of the version to be published.

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