

Scientific Contribution

Developmental Totipotency as a Normative Criterion for Defining the Moral Status of the Human Embryo

Thomas HEINEMANN

Philosophisch-Theologische Hochschule Vallendar

E-mail: t.heinemann@pthv.de

1. Introduction

Legislation concerning the handling of the human embryo in vitro differs widely among countries due to different moral and constitutional principles. Differences not only exist between far distant countries of different cultural, religious and political background and development, e.g. Japan and Germany, but also between neighboring countries. For example, while in Great Britain the use of human embryos for research purposes, especially for the sourcing of human embryonic stem cells (hES cells), is permitted in principle although made conditional upon having been approved by an authority,¹ the same action is prohibited in Germany.² Thus, scientists who wish to collaborate in a research project on human ES cells across national borders may encounter the problem of having to coordinate carefully their respective contributions to the joint research work in order to comply with the respective national legal provisions.

It is the task of ethics – and especially bioethics – as a scientific discipline to analyze the respective statutory regulations, make transparent and critically examine the moral grounds of the provisions made, and make them understandable to scientists and the society. With regard to the handling of human embryos and stem cell research this work is considered as prerequisite for converging as much as possible the respective national ethical arguments and legal provisions as well as identifying or generating arguments which may represent common ground for widely accepted standards and legal harmonization of this issue.

In this line, in this manuscript the legal and ethical situation concerning embryo research and research with embryonic stem cells in Germany will be explained and reasons given as to why there is an ongoing debate on this issue. Two problems can be identified which became arising with the advent of human embryonic stem cell technology and novel techniques for the cloning of animals. The first problem consists in an existing controversy on the moral status of the human embryo, the second problem concerns different views on

the question which entity should be considered as being a human embryo. Both problems are interdependent and are mainly focused on the normative meaning of the potential of a human embryo to develop into a born individual, especially on the notion of totipotency of a cell which, in the German law, is used to define a human embryo.³ The criterion of developmental totipotency in the ethical decision-making will be examined in four steps. First, a brief overview is provided on the legal framework currently in force in Germany concerning the handling of human embryos, taking a special focus on the notion of totipotency. Second, the ethical reasoning underlying the legal provisions will be outlined, including the significance of the argument of potentiality for the protection of human embryos, and on this basis the controversy concerning the moral status of the human embryo will be explained. Third, several problems will be outlined which emerge if the human embryo is defined on the basis of the notion of totipotency. Finally an understanding of totipotency will be proposed that may be useful for defining the moral status of the human embryo.

2. Legal framework with regard to the handling of human embryos in vitro in Germany

In Germany the relevant legislation concerning the handling of human embryos in vitro is laid down in the Embryo Protection Act and the Stem Cell Act. Both Acts represent supplementary penal provisions and, therefore, are part of the Penal Code making their violation a criminal offence.

2.1 Embryo Protection Act

As in many other countries specific legislation as to the handling of the human embryo in vitro was implemented in Germany as a consequence to the availability of In vitro-fertilization techniques. The Embryo Protection Act entered into force on January 1, 1991. The provisions set by the Act provide a strong protection of the human embryo in vitro, as demonstrated by the following examples: The Act prohibits the in vitro fertilization of a human egg cell for purposes other than bringing about a pregnancy of the woman from whom the egg cell originated (§1 (2)). Thus, the generation of human embryos for research purposes is prohibited by law, as is egg and embryo donation and surrogate motherhood. The Act allows to fertilize only that number of egg cells which will be transferred to the woman within one cycle of hormonal stimulation (§1 (5)). The idea behind this provision is that, at least in theory, no supernumerary embryos will result from in vitro fertilization procedures. The Act prohibits the sale of an embryo as well as, for a purpose not serving its

preservation, the handing-over, acquisition or use of an embryo (§2 (1)), and also prohibits to develop an embryo further outside the body for any purpose other than the bringing about of a pregnancy (§2 (2)). Thus, the use of an embryo for research purposes is prohibited. Cloning, as defined as causing artificially a human embryo to develop with the same genetic information as another embryo, fetus, human being or deceased person, is prohibited (§6) as is the formation of chimaerae and hybrid organisms using human embryos and their being transferred to a woman or an animal (7). Thus, the Embryo Protection Act sets very narrow limits to the generation and use of human embryos.

2.2 Stem Cell Act

In November 1998 James Thomson and colleagues from the University of Wisconsin, USA, published for the first time news of the successful in vitro cultivation of human embryonic stem cell lines (ES cells).⁴ As ES cells are derived from human embryos which are destroyed in the process of the sourcing of the cells, and since the use of human embryos for research purposes is prohibited by the Embryo Protection Act the question rose as to the conditions under which German scientists could take part in research using ES cells. After heated controversial public debate the German Parliament passed the Stem Cell Act in 2002 which takes to the solution of an import of ES cells from abroad under closely defined conditions.⁵ The Act even prohibits in principle the import into and the use of ES cells in Germany (§4 (1)), but also defines exceptions under which the import and use of ES cells may be allowed. The exception on importing ES cell lines covers only cell lines that were established before May 1, 2007, the date set by the Act (§4 (2) 1). With regard to the origin of the ES cell lines, only those cell lines which are derived from supernumerary embryos created for In vitro fertilisation, with no payment made for obtaining the permission to use the embryo for isolating ES cells, are eligible for import (§4 (2) 1). Research with ES cells is limited to high ranking goals aiming at progress in diagnosis, prevention, and therapy in humans (§ 5 (1)) and permission requires exhaustive preliminary studies as well as the lack of alternative research options (§ 5 (2)). The import and any use of ES cells has to be approved by an authority under the supervision of the Federal Ministry of Health and is reviewed by a Central Ethics Advisory Commission consisting of scientists, physicians, theologians and ethicists advising the authority.

2.3 Definition of the human embryo

Both, the Embryo Protection Act and the Stem Cell Act, include a legal definition of the term embryo in order to specify the entities which fall under the provisions made by the Acts.

The definition in Paragraph 8 of the Embryo Protection Act from 1990 reads:
“For the purpose of this Act, an embryo already means the human egg cell, fertilized and capable of developing, from the time of fusion of the pronuclei, and further, each totipotent cell removed from an embryo that is assumed to be able to divide and to develop into an individual under the appropriate conditions for that.” (§ 8 (1)).

Interestingly, a different definition was used in Paragraph 3 of the Stem Cell Act in 2002:

“For the purpose of the present Act embryo already means each human totipotent cell that is assumed to be able to divide and to develop into an individual under the appropriate conditions for that.” (§ 3(4)).

Thus, with regard to a human embryo, both Acts are referring to a human totipotent cell. The concept of totipotency was first introduced in 1912 by the German developmental biologist Wilhelm Roux (1850-1924).⁶ At that time scientists were interested in exploring the mechanisms of morphogenesis taking place during the development of an organism. Wilhelm Roux, for example, destroyed in two-cell stage frog embryos one of the two blastomeres using a hot needle and observed the remaining blastomere developing into an embryo comprising only half a frog. From these experiments he concluded that each cell of the embryo was already determined as to being able to produce only certain structures of the whole organism. Moreover, Roux concluded that bringing forth the structure of the organism was performed by the cell itself, not by environmental factors the latter being the prevailing view at that time. Thus, Roux believed that all the factors (determinants) necessary for the development of an embryo are already in place in the embryo and determine and drive its development. A few years later another German scientist, Hans Driesch (1867-1941), disproved the first conclusion of Wilhelm Roux but confirmed the second. He separated the two blastomeres of a sea urchin embryo by vigorous shaking and observed that each blastomere had the potential to develop into a complete sea urchin larva. Driesch concluded that the early blastomeres are *not* determined to produce only certain predefined structures of an organism but have the potential to develop into a whole organism. This potential was called totipotency and related to a single cell of an embryo which owns the potential to develop into a whole harmonically shaped viable organism. It is obvious that this concept of totipotency was adopted by the Embryo Protection Act and the Stem Cell Act in defining an embryo.

In contemporary developmental biology the developmental potential of *totipotency* is distinguished from that of *pluripotency* which defines the potential of a cell to differentiate into all cell types of an organism including the germ cells but not supporting the organization of the cells into a harmonically shaped viable organism. Once established from

an embryo, ES cells are considered as being pluripotent cells, but not totipotent embryos, and that is why they do not fall under the scope of the Embryo Protection Act in Germany.

3. The ethical reasoning underlying the legal provisions

3.1 Provisions made by the German Basic Law

As pointed out above, the ongoing debate in Germany centers on the legal and moral status of the human embryo, i.e. on the question what good the embryo represents in terms of a moral assessment, and to the question which entity should be considered as being a human embryo. Both questions are closely related to each other and for both questions the provisions made by the German Basic Law (Grundgesetz) are of key relevance.

Article 1, Paragraph 1, of the Basic Law reads:

“Human dignity shall be inviolable. To respect and protect it shall be the duty of all state authority.”

According to the Basic Law, therefore, every man is subject to the respect of human dignity, and the goal of the state authority and, moreover, the goal of the whole state itself is to respect the dignity of all members of the state and to protect their dignity against violation. Philosophically, the concept of dignity of man as laid down in Article 1 is considered by many to trace back to the German philosopher Immanuel Kant, who, as a key figure of the Age of Enlightenment in Europe, gave reasons for the notion that each member of humankind is not entirely determined by nature but capable to set ends to itself. Therefore, man is a subject capable of moral reasoning, and that means man is a subject which is responsible for its actions. Kant characterizes such moral subject as being a person. Because persons are moral subjects, they own dignity, and the essence of dignity is to be respected by others. It is a central point that Kant attributes dignity not only to persons who *actually* realize moral reasoning but to all living individuals who are *capable* of realizing moral reasoning and who represent, therefore, ends in itself. Thus, the respect of human dignity is a fundamental moral law, and the Basic Law in Germany, therefore, is founded in that moral law. This law is characterized by the unconditional demand never to treat a moral subject only as a means, but always also as an end in itself. To treat a moral subject only as a means would mean to violate its dignity.

Based on this philosophical and legal background, the question of whether a human embryo has to be considered as a person and whether the notion of human dignity includes, or applies to, the human embryo is of key importance for the judgement as of what level of protection is owed to an embryo, i.e. whether or not a human embryo can be used for

research. If a human embryo owns dignity – or if the protection called for by the notion of human dignity applies to the embryo –, the Right of Life as laid down in Article 2, Paragraph 2, of the Basic Law would apply as a personal right of the embryo and would strictly prohibit its destruction. In this case, the Right of Life would set clear restrictions to the freedom of research as laid down in Article 5 of the Basic Law.

Although the Embryo Protection Act imposes a strict ban on any manipulation involving a human embryo if the manipulation does not aim exclusively at the preservation of the embryo, the question of whether or not human dignity applies to human embryos is not resolved in Germany. The law itself does not make a statement on this matter whatsoever, and although many lawmakers do interpret the Embryo Protection Act in a sense, that the embryo is protected because the Law considers it to be a person, others do not. In two judgments on abortion the German Federal Constitutional Court clearly spelt out that an embryo after implantation in the mother's womb owns dignity, but refused to make statements to the moral and legal status of the preimplantation embryo in vitro. However, in the ongoing debate concerning this question the inherent totipotent developmental capacity of the embryo plays an important role since it corresponds to the well-known philosophical argument of potentiality which, as will be explained in detail further on, is considered by many as constituting the moral status of the human embryo.

3.2 Different positions on the moral status of the embryo

In Germany, as in other western countries, basically two positions on the moral status of the embryo can be distinguished.⁷ One – restrictive – position holds that, beginning with the existence as a single totipotent cell, the embryo ought to be acknowledged as a good which deserves unrestricted protection as it is granted to any born individual. The other – gradualist – position claims that the moral status of an early embryo differs from that of later stages and, accordingly, the level of protection to be granted increases as certain stages of development are reached.

For proponents of the restrictive position the notion of human dignity applies to the early embryo, since right from the beginning the embryo has the potential to develop into a moral subject. There is no other goal of a human embryo than to develop into a born human individual and, therefore, each embryo owns the *potentiality* to be a moral subject. Moreover, the embryo and the moral subject are identical, both representing the same human being. The *identity* of moral subject and embryo corresponds to the *continuity* in the development of the embryo, which does not allow for the identification of certain developmental stages as a basis for the moral assessment of the embryo's status. The inherent potentiality for continuous development as an identical living being is already

present in a single cell stage embryo when the individual genome directing the development of the human embryo is constituted. As a consequence, on the basis of the arguments of potentiality, identity and continuity, in combination with the fact that the embryo belongs to the human species and its only inherent goal is to develop into a born human being, proponents of this position call for the full protection of the embryo starting from the earliest beginnings of life as a totipotent cell. The four arguments of species, continuity, identity and potentiality, which are abbreviated by their first characters as so-called SCIP arguments, are interdependent, with the argument of potentiality representing the leading argument since the arguments of continuity and identity may be viewed as an explanation of potentiality.

In contrast, proponents of the gradualist position claim that an embryo or fetus should only be granted the same level of protection as that applied to a moral subject if certain stages of development or certain qualities characteristic of a moral subject have been reached. Proponents of the gradualist position regard certain conditions in the normal development of the human embryo to be relevant for the extent to which an embryo must be protected. Those conditions include the implantation of the embryo in the mucosa of the uterus, the biological individuation, i.e. the loss of the early embryo's potential to divide into two or more embryos, the occurrence of heart action, the appearance of neurons, first movements of the embryo in the mother's womb (quickening), and others.

While neither the German Basic Law nor certain decisions by the Federal Constitutional Court (Bundesverfassungsgericht) nor the Embryo Protection Act *explicitly* deal with the moral status of the embryo in vitro, they rely on an assessment that is rather close to the restrictive position. This applies also to the ethical reasoning underlying the Stem Cell Act which left the ethical standards set by the Embryo Protection Act unchanged, thus considering the destruction of early human life as not being in line with the protection of human dignity guaranteed in the German Basic Law. However, even on the basis of the restrictive position the question rises whether each totipotent entity has to be protected or, put in another way, whether totipotency, as a single criterion, is sufficient for defining a human embryo.

4. Problems with regard to the legal definition of the human embryo

According to the Embryo Protection Act an embryo already means (1) the human egg cell, fertilized and capable of developing, from the time of fusion of the pronuclei, and (2) further, each totipotent cell removed from an embryo that is assumed to be able to divide and to develop into an individual under the appropriate conditions for that. Based on this

definition the term embryo covers both, embryos generated “naturally” by fertilization of a human egg cell as well as totipotent cell entities created “artificially” by embryo splitting or other techniques. On this basis the Act makes normative distinctions between embryos generated by techniques allowed by the Act and embryos created by techniques prohibited by law. However, this distinction cannot be made on the basis of the totipotent developmental potential of an embryo as this potential applies to all embryos. Thus, either the definition of a human embryo requires additional criteria beyond the criterion of totipotency or the notion of totipotency tacitly carries a normative meaning which allows to distinguish between human embryos of different origin. With regard to the criterion of totipotency for defining an embryo a variety of questions are discussed in Germany which can be assigned to three areas, (1) the biological verification of totipotency, (2) the ethical content of the criterion of totipotency, and (3) the notion of totipotency as a useful legal criterion.

4.1 Biological verification of totipotency

With regard to the verification of totipotency there are currently no biological markers available to identify the totipotent state of a cell. While in “natural” embryos the knowledge of their potential of developing into a born individual is based on common experience, totipotency remains just an assumption in “artificially” created, i.e. cloned, human embryos as they, by ethical reasons, cannot be brought to term just for the scientific purpose of confirming their being totipotent. Therefore, the possible totipotent developmental capacity of “artificially” created human embryos can only be deduced from animal studies, with considerable uncertainty remaining as to whether these results are transferrable to the human species. However, not only is it difficult to confirm totipotency in artificially created human embryos, but the meaning of totipotency remains unclear in “natural” embryos as well. It is well known that more than 70% of naturally fertilized embryos are unable of either implanting into the mucosa of the uterus or further developing after implantation. In a biological understanding of totipotency those embryos can hardly be considered as being totipotent which may lead to the conclusion that the criterion of totipotency does not apply to the majority of “natural” embryos. Moreover, the criterion of totipotency gives no answer to the question as to which state of development needs to be reached in order to get the *totipotent* developmental capacity of the embryo confirmed. The Embryo Protection Act holds the fertilized human egg cell to be capable of development in the first 24 hours after fusion of the pronuclei except when it is established before expiry of this time period that the fertilized egg cell will not develop beyond the one cell stage (§8 (2)). However, the Act makes no provision with regard to the endpoint of totipotency. Thus, if understood as a

biological criterion totipotency can only be verified *ex post* which makes it a parameter difficult to assess.

4.2 Ethical content of the notion of totipotency

With regard to the ethical content of the notion of totipotency the artificial creation of a totipotent cloned human embryo can hardly be considered without taking into account the creator who, by way of creating the embryo, pursues his own objectives which are imposed upon the embryo. Thus, the artificial creation of a cloned totipotent cell corresponds to ends which are not founded in the existence of the embryo itself. Yet, at least as held by the restrictive position, the moral status of a human embryo is founded in its potentiality to be an end in itself which raises the question whether an artificially created cloned totipotent cell may represent an end in itself. Rather, this cell was created in a defined way for the ends and by the will of its creator. This action may be considered as a violation against the dignity of the person developing from this embryo as this person carries in its very existence the ends of the creator and will not be able to free itself from being a means to the ends set by the creator. Thus, fertilization of an egg cell which is accompanied with the random distribution of genetic traits may be considered as an important criterion with regard to human dignity. If so and if the conditions of the bringing into existence a human embryo represents an important criterion for its moral status, the question rises as to whether defining an embryo by its totipotent developmental capacity will be sufficient.⁸

Another criticism regarding the criterion of totipotency relates to a logical inconsistency which becomes relevant if totipotency is used in an exclusively biological understanding of the term. In a biological understanding totipotency cannot be simply used as a normative criterion since deducing a normative statement from the as-is state will represent a logical fallacy. Therefore, if totipotency is used to define a human embryo the understanding of totipotency and the relationship between totipotency and the corresponding normative argument of potentiality needs to be clarified.

4.3 The notion of totipotency as a useful legal criterion

When the Embryo Protection Act was enacted in 1991 the legislator was interested in solving the question as to how to protect appropriately the human embryo *in vitro*. At that time, only two ways of generating a human embryo outside the body were known to be applicable, i.e. the fertilization of a human egg cell and the mechanical splitting of the totipotent blastomeres of an existing human embryo, the latter method imitating the natural way of generating twins. Thus, at that time there was almost no dispute over the question as of which entity represents a human embryo. This question became virulent only

later on. In 1993 Nagy and coworkers published for the first time the method of tetraploid embryo complementation which comprises pluripotent stem cells being surrounded with cells of a tetraploid embryo either by injecting the pluripotent stem cells into a tetraploid blastocyst or by sandwiching the cells. In numerous animal studies it was demonstrated that this conglomeration of different cells can be brought to term, often resulting in healthy animals. Moreover, in 1997 Wilmut and coworkers published the creation of Dolly the sheep by somatic cell nuclear transfer. This method has been successfully applied in numerous animal species so far. Thus, highly artificial methods for generating cell entities capable to develop into born individuals have been developed during the last 20 years. As in other countries in Germany lawmakers were highly interested to prevent these techniques from being applied to humans. Therefore, their key question was whether the use of these techniques in human cells was covered by the law, i.e. whether or not the cell entities resulting from these techniques were to be considered as human embryos. Since in animal studies these entities were found to be totipotent, and since “each totipotent cell” was defined by the Embryo Protection Act as representing an embryo, those entities were considered as embryos. As they represent cloned embryos their bringing into existence is prohibited by the Act. However, designating artificially created human totipotent cells as human embryos by way of their being totipotent required a tacit change from the notion of totipotency being a *criterion* used to define the human embryo to being the *reason* for defining a cell as being an embryo. In addition, the notion of totipotency needed to be interpreted in an exclusively biological meaning of the term. As a result each biologically totipotent human cell was to be considered as a human embryo. Obviously this view was transferred into the definition of the embryo as laid down in the Stem Cell Act from 2002 which in defining the human embryo exclusively focuses on the notion of totipotency.

The impact of this interpretation becomes evident in a hypothetical thought experiment. In 2006 the Japanese scientist and 2012 Nobel Prize Winner Shinya Yamanaka and his coworkers published a method to reprogram somatic cells back into an embryonic stage by using four different bioactive molecules.⁹ The resulting cells are called induced pluripotent stem cells (iPS cells). As of now, neither is it known on a molecular level what exactly happens within the cell during reprogramming nor is the molecular basis of pluripotency and totipotency known in detail. Thus, although unlikely it cannot be excluded that the cells or at least some of the cells may temporarily proceed into a state of developmental totipotency during the reprogramming procedure. Assuming that this is the case and taking the notion of totipotency, understood in an exclusively biological meaning of the term, as a *reason* for defining an embryo, these reprogrammed totipotent cells would

have to be considered as cloned embryos. On the basis of this scenario according to the Embryo Protection Act the reprogramming of cells would be prohibited by law.

5. Totipotency as a relevant criterion for defining the moral status of a human embryo

(1) It is obvious that on the basis of this interpretation neither a useful definition of a human embryo can be reached nor are the consequences acceptable for scientists and the public. Thus, the notion of totipotency either should be abandoned from legislation as is demanded especially by proponents of the gradualist position, or needs to be redefined. For the latter alternative the following considerations could be taken into account. Totipotency is a feature necessary to distinguish a single-cell embryo from all other cells not capable of developing into a born individual. Completely abandoning the notion of totipotency from the legal definition of a human embryo may result in problematic consequences. This message was brought home by a recent ruling of the European Court of Justice. In a decision made in 2011 on a patent claim of a German stem cell scientist which was opposed by the Greenpeace activists group, the Court considers as a human embryo “any human ovum after fertilisation, any non-fertilised human ovum into which the cell nucleus from a mature human cell has been transplanted and any non-fertilised human ovum whose division and further development have been stimulated by parthenogenesis”.¹⁰ As it is well known that human embryos generated by parthenogenesis are not able to develop beyond a few days period of time this definition of a human embryo was irritating. In defining the embryo the Court either did not take into account the criterion of the totipotent developmental capacity of an embryo or considered totipotency as given in human parthenotes even in view of their very limited developmental capacity. This definition taken by the Court was hardly understandable for proponents of both, the gradualist *and* the restrictive position.

(2) Totipotency is not to be considered as being the *reason* for defining a cell as an embryo but represents a *criterion* by which an embryo is defined. As a consequence, not is each totipotent cell necessarily to be considered as an embryo, however, each single-cell embryo represents necessarily a totipotent cell. Thus, highly artificially created totipotent human cells, e.g. cloned cells, must not necessarily be considered as human embryos.

(3) Totipotency is not to be considered as an exclusively biological criterion. Although the notion of totipotency describes the biological developmental potential of a cell, totipotency closely correlates to the normative argument of potentiality which constitutes the protection of the embryo on the basis of human dignity.

(4) Totipotency is not to be considered as representing the only criterion to define a human embryo. If the notion of human dignity, by way of the argument of potentiality, applies to the embryo, the way of bringing into existence an embryo must be free of aims pursued by other human beings. Thus, the way of bringing into existence an embryo appears to be normatively relevant and may be used as an additional criterion for defining a human embryo.

Notes

¹ Human Fertilisation and Embryology Act 2008, see

http://webarchive.nationalarchives.gov.uk/20130107105354/http://www.dh.gov.uk/en/Publicationsandstatistics/Legislation/Actsandbills/DH_080211 (retrieved May 31, 2015).

² German Embryo Protection Act. Gesetz zum Schutz von Embryonen, December 13, 1990 (BGBl. I S. 2746).

³ Paragraph 8,1; German Embryo Protection Act. Gesetz zum Schutz von Embryonen, December 13, 1990 (BGBl. I S. 2746).

⁴ Thomson, J. A., Itskovitz-Eldor, J., Shapiro, S. S., Waknitz, M. A., Swiergiel, J. J., Marshall, V. S., Jones, J. M. (1998). Embryonic stem cell lines derived from human blastocysts. *Science* 282: 1145-1062.

⁵ Stem Cell Act. Gesetz zur Sicherstellung des Embryonenschutzes im Zusammenhang mit Einfuhr und Verwendung menschlicher embryonaler Stammzellen, 28. Juni 2002 (BGBl. I S. 2277).

⁶ Baranzke, H.: Der menschliche Embryo — Naturzweck oder Handlungszweck? Eine Kritik an Totipotenz und Potentialitätsargument in der Embryonenschutzdiskussion. In: Heinemann T., Dederer, H.-G., Cantz, T., *Entwicklungsbiologische Totipotenz in Ethik und Recht*. Göttingen 2015, p. 167 ff.

⁷ Heinemann, T.: Ethische Beurteilungskriterien für die Forschung an Stammzellen. In: Heinemann, T., Kersten K. *Stammzellforschung. Naturwissenschaftliche, rechtliche und ethische Aspekte*. Freiburg, München 2007. p. 201 ff.

⁸ Advena-Regnery, B.: Natürlicher Embryo — geeignetes Wertprädikat für die Bioethik? In: Heinemann T., Dederer, H.-G., Cantz, T., *Entwicklungsbiologische Totipotenz in Ethik und Recht*. Göttingen 2015, p. 247 ff.

⁹ Takahashi, K., Tanabe, K., Ohnuki, M., Narita, M., Ichisaka, T., Tomoda, K., Yamanaka, S. (2007). Induction of pluripotent stem cells from adult human fibroblasts by defined factors. *Cell* 131 (5): 861-872.

¹⁰ European Court of Justice, 18.10.2011 - C-34/10.