[Specification]

[Title of the Invention]

TRANSFORMATION PLASMID

[Technical field]

[0001]

The present invention relates to a plasmid for transformation used for the production of a transformed anaerobic bacterium useful as a gene transfer carrier for treating an anaerobic disease such as solid tumor, the plasmid comprising an expression cassette containing a secretory signal peptide that functions in the anaerobic bacterium, and the plasmid being a non-shuttle plasmid. The invention also relates to a gene transfer carrier consisting of an anaerobic bacterium which has been transformed with said transforming plasmid, and to a pharmaceutical composition comprising the gene transfer carrier, as well as to an agent for treating an anaerobic disease comprising the gene transfer carrier.

[0002]

The invention further relates to a DNA fragment useful for the production of the transformed anaerobic bacterium for treating the anaerobic disease, consisting of a nucleotide sequence encoding a novel secretory signal peptide.

[Background Art]

[0003]

Recently, in the therapies of a malignant tumor, methods of using a transformed anaerobic bacterium as a carrier for gene transfer have been highlighted. For instance, methods of such as using a transformed *Clostridium* for transferring to the tumor site a gene that expresses nitroreductase, an enzyme that transforms a prodrug of an antitumor substance to the antitumor substance, has been proposed (see Patent Literatures 1 to 3).

[0004]

Furthermore, methods of using invasive anaerobic bacteria such as *Salmonella*, enteroinvasive *Escherichia coli*, *Listeria* and *Shigella* for transferring a gene encoding a nucleic acid that abolishes or interferes the expression of a gene involved in an anaerobic disease by RNA interfering to tumor cells, such as small interfering RNAs

(siRNAs), short interfering RNAs and short hairpin RNAs, have been investigated (see Patent Literatures 4 to 6).

[0005]

Nevertheless, since all these microorganisms are pathogenic bacteria which have been mutated to be avirulent, the possibility cannot be denied that back mutation might be happened to return to the original pathogenic bacteria and exert harmfulness. Furthermore, for their motility and invasiveness, these bacteria might express their effect not only in the disease tissue but also in a normal tissue, causing a systemic side effect. Thus, their safety is still a matter of concern.

[0006]

The inventors focused on *Bifidobacterium* which is a non-pathogenic enteric bacterium being present in human intestine to form a flora and which is known to be an extremely safe obligate anaerobe, and developed a method for treating a malignant tumor using a transformed bacterium of this *Bifidobacterium*.

The inventors then developed a *Bifidobacterium longum* 105A which have been transformed to express cytosine deaminase (hereinbelow referred to as CD), which is an enzyme that converts 5-fluorocytosine (hereinbelow referred to as 5-FC) (a prodrug of an antitumor substance 5-fluorouracil (hereinbelow referred to as 5-FU)) to 5-FU (see Patent Literatures 7 and 8).

[0007]

This transformed *Bifidobacterium* is characterized in that when being administered into a model animal of solid tumor, which is an anaerobic disease, it specifically colonizes and proliferates in the anaerobic disease tissue which is in hypoxic condition, whereas it quickly disappears in a normal tissue which is not in a hypoxic environment (see non-Patent Literatures 1 and 2).

Furthermore, this transformed *Bifidobacterium* is also characterized in that it does not exhibit antigenicity even when being administered intravenously. It may therefore be expected as an excellent therapeutic for malignant tumor.

[0008]

Since these transformed bifidobacteria have been transformed using an *Escherichia coli* (*E. coli*) - *Bifidobacterium* shuttle plasmid such as pBLES100-S-eCD

and pAV001-HU-eCD-M968, if they are horizontally transferred to an *E. coli*, they might be replicated in that *E. coli*. Therefore, the inventors improved the plasmid to solve this problem and developed a non-shuttle plasmid pBifiCD which does not have a replication origin that functions in *E. coli* (see Patent Literature 9).

[0009]

On the hand, since these non-shuttle plasmids did not possess a secretory signal, the transformed bifidobacteria could not secrete expressed CD extracellularly.

Therefore, it has been desired to develop a secretory signal peptide that is capable of functioning in *Bifidobacterium* and secreting expressed proteins from the bacteria cell.

As examples of secretory proteins of *Bifidobacterium*, amylase of *Bifidobacterium adolescentis*, and Sec1, Sec2 and Sec 3 of *Bifidobacterium breve* have been reported, and plasmids introduced their secretory signals have also been reported.

[0010]

For example, *Bifidobacterium longum* MG1 has been reported, which has been transformed with an *E. coli* - *Bifidobacterium* shuttle plasmid pYBamy59 in which a secretory signal peptide gene of *Bifidobacterium adolescentis* amylase have been transferred (see Patent Literature 3).

Also, *Bifidobacterium breve* UCC2003 has been reported, which has been transformed with an *E. coli* - *Bifidobacterium* shuttle plasmid such as pESH86 or pESH87 in which a fusion gene of a secretory signal peptide of Sec2 of *B. breve* and human fibroblast growth factor 2 (FGF-2) have been transferred (see Patent Literature 4).

[0011]

Furthermore, there have been reports of an expression cassette containing a promoter and a signal sequence derived from *Bifidobacterium*, in particular an expression cassette containing a signal of *BL1181* gene product or a signal sequence of *amyB* gene product; indeed, a significant secretion of the expressed protein was confirmed in *B. breve* and *B. longum* (see, Patent Literature 10).

[0012]

Nevertheless, said plasmids are all *E. coli* - *Bifidobacterium* shuttle plasmid. A non-shuttle plasmid that does not possess a replication origin that functions in *E. coli* and, that has a secretory signal that functions in *Bifidobacterium*, such as a plasmid of the present invention, was not known. Moreover, it has not been ascertained whether any of these secretory signals function in a bacterial strain other than those already confirmed. Furthermore, the secretion of target protein by the transformed bacterium is expected to be small. Therefore, it was also desired to develop a secretory signal peptide for practical use that is capable of exerting a good secretory function.

[Citation List]

[0013]

[Patent Literature 1] US Patent No. 6416754

[Patent Literature 2] US Patent No. 6652849

[Patent Literature 3] US Patent Application No. 2003/0103952

[Patent Literature 4] JP A No. 2008-519002

[Patent Literature 5] JP A No. 2008-92956, WO2006-066048

[Patent Literature 6] WO 2008-091375

[Patent Literature 7] JP A No. 2002-97144

[Patent Literature 8] WO 2007-136107

[Patent Literature 9] WO 2009-128272

[Patent Literature 9] WO 2010-126073

[0014]

[Non-Patent Literature 1] Yazawa et al., Cancer Gene Therapy, Vol. 7, No. 2, 2000: pp 269-274

[Non-Patent Literature 2] Yazawa et al., Breast Cancer Research and Treatment, Vol. 66, 2001: pp 165-170

[Non-Patent Literature 3] Seong et al., Biotechnology Letters, 2006, Vol. 28: pp 163-168

[Non-Patent Literature 4] Shkoporov et al., Biotechnology Letters, 2008 Vol.30: pp 1983-1988

[Summary of the Invention]

[Problems to Be Solved by the Invention]

[0015]

The object of the present invention is to provide a transforming plasmid for the production of a transformed anaerobic bacterium, the plasmid that possesses a secretory signal that functions in the anaerobic bacterium and that is a non-shuttle plasmid which does not possess a replication origin that functions in an bacterium other than said anaerobic bacterium, and to provide a transformed anaerobic bacterium transformed with said transforming plasmid, a gene transfer carrier consisting of said transformed anaerobic bacterium, a pharmaceutical composition comprising said gene transfer carrier, and an agent for treating an anaerobic disease comprising said transformed anaerobic bacterium.

[0016]

Another object of the present invention is to provide a gene transfer carrier consisting of a transformed anaerobic bacterium transformed with said transforming plasmid, a pharmaceutical composition comprising said gene transfer carrier, and an agent for treating an anaerobic disease comprising said transformed anaerobic bacterium.

Furthermore, another object of the present invention is to provide a novel secretory signal that is capable of exerting its function in, e.g., *Bifidobacterium longum* 105A.

[Means for Solving the Problems]

[0017]

The inventors previously produced plasmids such as pBLES100-S-eCD and pAV001-HU-eCD-M968 which contains a gene that expresses CD, one of proteins having an activity to convert a precursor of an antitumor substance to the antitumor substance. The inventors then found and reported that an obligate anaerobic

bacterium that underwent a recombination with these plasmids, e.g., *Bifidobacterium longum* 105A/pBLES100-S-eCD and *Bifidobacterium longum* 105A/pAV001-HU-eCD-M968 could be expected to be a useful therapeutic for malignant tumor (see Patent Literatures 7 and 8).

[0018]

The plasmids pBLES100-S-eCD and pAV001-HU-eCD-M968 used for the production of the transformed bacteria in Patent Literatures 7 and 8 above were both *E. coli* - *Bifidobacterium* shuttle plasmids, and therefore in the case they are horizontally transferred to *E. coli*, they might be replicated in it.

[0019]

Nevertheless, in a method of treating malignant tumor using a transforming gene transfer carrier, it is critical that the transforming gene in the gene transfer carrier is not to be horizontally transferred to any pathogenic bacteria or aerobic or facultative anaerobic bacteria other than said gene transfer carrier, and that even if it was horizontally transferred, it will not be replicated in those other bacteria. Thus, the plasmid should be a non-shuttle plasmid that does not have a replication origin that functions in a bacterium other than the transformed bacterium, i.e., that is not mutually replicated in both the transformant and other bacteria.

[0020]

Accordingly, the inventors improved the plasmid to solve this problem and developed a non-shuttle plasmid pBifiCD which does not possess an origin of replication that functions in *E. coli* (Patent Literature 9).

On the other hand, these plasmids are all transforming plasmid having no secretory signal and therefore the transformed bacteria that underwent the recombination using these plasmids do not extracellularly secrete expressed CD. Thus, there still remains the problem that the expression of CD does not directly reflect to CD enzymatic activity, i.e., the drug efficacy.

[0021]

Moreover, in the case when the bacterium is not to produce an enzyme such as CD that convert a prodrug to an antitumor substance but to produce an antitumor protein or antitumor nucleic acid, it is necessary to induce the bacterium to

extracellularly release produced antitumor substance, and therefore the bacterium has to be killed after its proliferation in the anaerobic disease tissue. Therefore, the inventors reached a conclusion that a transforming plasmid having a secretory signal that functions in an obligate anaerobic bacterium, especially in *Bifidobacterium*, is preferred. The inventors devotedly continued the research and completed the invention.

[0022]

Namely, the present invention relates to the followings:

[1] A plasmid for producing a transformed anaerobic bacterium, the plasmid comprising an expression cassette containing a secretory signal that functions in the anaerobic bacterium, and the plasmid being a non-shuttle plasmid.

[2] The plasmid according to [1], wherein the anaerobic bacterium is *Bifidobacterium*.

[3] The transforming plasmid according to [1] or [2], wherein the secretory signal peptide is derived from *Bifidobacterium*.

[4] The transforming plasmid according to [3], wherein the secretory signal peptide is derived from *Bifidobacterium longum*.

[0023]

[5] The transforming plasmid according to any one of [1] to [4], wherein the secretory signal is a DNA according to any one of the nucleotide sequences of SEQ ID No.: 6 to 28, or said sequence in which one or several nucleotide thereof are deleted, substituted or added.

[6] The transforming plasmid according to [5], wherein the secretory signal is a nucleotide sequence of SEQ ID No.: 6, 7, 8, 9, 12, 14, 15, 17, 21, 25 or 28, or said sequence in which one or several nucleotide thereof are deleted, substituted or added.

[0024]

[7] The transforming plasmid according to [6], wherein the secretory signal is a DNA according to the nucleotide sequence of either SEQ ID No.: 8 or 25 or a single nucleotide polymorphism thereof.

[8] The transforming plasmid according to any one of [1] to [7], wherein a promoter contained in the expression cassette is a DNA according to any one of nucleotide

sequences of promoter regions of SEQ ID Nos.: 29 to 44 or the nucleotide sequence of SEQ ID No.: 45, or said sequence in which one or several nucleotide thereof are deleted, substituted or added.

[0025]

[9] The transforming plasmid according to [8], wherein the promoter contained in the expression cassette is a nucleotide sequence of a promoter region of SEQ ID No.: 35 or the nucleotide sequence of SEQ ID No.: 45, or said sequence in which one or several nucleotide thereof are deleted, substituted or added.

[10] The transforming plasmid according to any one of [1] to [9], wherein a terminator contained in the expression cassette is a DNA according to the nucleotide sequence of SEQ ID No.: 46, or said sequence in which one or several nucleotide thereof are deleted, substituted or added.

[0026]

[11] The transforming plasmid according to any one of [1] to [10], wherein a target gene contained in the expression cassette is a gene encoding a fluorescent protein.

[12] The transforming plasmid according to any one of [1] to [10], wherein a target gene contained in the expression cassette is a gene encoding a protein having an antitumor activity.

[0027]

[13] The transforming plasmid according to [12], wherein the protein having an antitumor activity is one selected from the group consisting of cytokines such as interferon (IFN)-α, IFN-β, IFN-γ, granulocyte-macrophage colony-stimulating factor (GM-CSF), interleukin (IL)-1α, IL-1β, IL-2, IL-3, IL-4, IL-6, IL-7, IL-10, IL-12, IL-13, IL-15, IL-18, tumor necrosis factor (TNF)-α, lymphotoxin (LT)-β, TNF-related apoptosis inducing ligand (TRAIL), granulocyte colony-stimulating factor (G-CSF), macrophage colony-stimulating factor (M-CSF), macrophage migration-inhibitory factor (MIF), leukemia-inhibitory factor (LIF), T cell activator co-stimulators B7 (CD80) and B7-2 (CD86), Kit ligand and oncostatin M, and anti-angiogenic agents such as endostatin, angiostatin, kringle-1, kringle-2, kringle-3, kringle-4 and kringle-5.

[0028]

[14] The transforming plasmid according to [13], wherein the protein having an antitumor activity is either tumor necrosis factor (TNF)-α or TNF-related apoptosis inducing ligand (TRAIL).

[15] The transforming plasmid according to any one of [1] to [10], wherein the target gene is a gene encoding a protein having an activity to convert a precursor of an antitumor substance to the antitumor substance.

[16] The transforming plasmid according to [15], wherein the protein having an activity to convert a precursor of an antitumor substance to the antitumor substance is one selected from the group consisting of cytosine deaminase, nitroreductase and ß-glucronidase.

[0029]

[17] The transforming plasmid according to any one of [1] to [10], wherein the target gene is a gene encoding a protein having a therapeutic activity for an ischemic disease.

[18] The transforming plasmid according to [17], wherein the protein having a therapeutic activity for an ischemic disease is one selected from the group consisting of proteins having a proangiogenic activity such as fibroblast growth factor 2 (FGF2), endothelial cell growth factor (ECGF), vascular endothelial growth factor (VEGF) and hepatocyte growth factor (HGF).

[19] The transforming plasmid according to any one of [1] to [10], wherein the target gene is a nucleic acid having a therapeutic activity for an anaerobic disease.

[0030]

[20] The transforming plasmid according to [19], wherein the nucleic acid having a therapeutic activity for an anaerobic disease is an siRNA associated with at least one tumor cell growth factor selected from the group consisting of fibroblast growth factor 2(FGF2), endothelial cell growth factor (ECGF), vascular endothelial growth factor (VEGF) and hepatocyte growth factor (HGF).

[21] The transforming plasmid according to any one of [1] to [20], comprising a DNA sequence according to the nucleotide sequence of SEQ ID No.: 5, or said sequence in which one or several nucleotide thereof are deleted, substituted or added (pBifi-SP3B-TNF alpha).

[0031]

[22] A gene transfer carrier consisting of an anaerobic bacterium transformed with the transforming plasmid according to any one of [1] to [21].

[23] The gene transfer carrier according to [22], wherein the anaerobic bacterium is an avirulent enterobacterium.

[24] The gene transfer carrier according to [22] or [23], wherein the anaerobic bacterium is *Bifidobacterium*.

[0032]

[25] The gene transfer carrier according to [24], wherein the *Bifidobacterium* is a species selected from the group consisting of *Bifidobacterium adolescentis*, *Bifidobacterium angulatum*, *Bifidobacterium animalis*, *Bifidobacterium asteroides*, *Bifidobacterium bifidum*, *Bifidobacterium boum*, *Bifidobacterium breve*, *Bifidobacterium catenulatum*, *Bifidobacterium choerinum*, *Bifidobacterium coryneforme*, *Bifidobacterium cuniculi*, *Bifidobacterium denticolens*, *Bifidobacterium dentium*, *Bifidobacterium gallicum*, *Bifidobacterium gallinarum*, *Bifidobacteria globosum*, *Bifidobacteria indicum*, *Bifidobacterium infantis*, *Bifidobacteria inopinatum*, *Bifidobacterium lactis*, *Bifidobacterium lactentis*, *Bifidobacterium liberorum*, *Bifidobacterium longum*, *Bifidobacterium magnum*, *Bifidobacterium merycicum*, *Bifidobacterium minimum*, *Bifidobacterium mongoliense*, *Bifidobacterium parvulorum*, *Bifidobacterium pseudocatenulatum*, *Bifidobacterium pseudolongum*, *Bifidobacterium psychroaerophilum*, *Bifidobacterium pullorum*, *Bifidobacterium ruminale*, *Bifidobacterium ruminantium*, *Bifidobacterium saeculare*, *Bifidobacterium scardovii*, *Bifidobacterium subtile*, *Bifidobacterium suis*, *Bifidobacterium thermacidophilum* and *Bifidobacterium thermophilum*.

[0033]

[26] The gene transfer carrier according to [25], wherein the *Bifidobacterium* is *Bifidobacterium longum*.

[27] The gene transfer carrier according to any one of [22] to [26], being capable of growing in a tumor tissue in an anaerobic environment and being capable of expressing and secreting at least one protein or nucleic acid that is useful for diagnosis or treatment of an anaerobic disease.

[28] The gene transfer carrier according to [27], wherein the protein that is useful for diagnosis of an anaerobic disease is a fluorescent protein.

[29] The gene transfer carrier according to [27], wherein the protein that is useful for treatment of an anaerobic disease is a protein having an antitumor activity.

[0034]

[30] The gene transfer carrier according to [28], wherein the protein having an antitumor activity is one selected from the group consisting of cytokines such as interferon (IFN)-α, IFN-ß, IFN-γ, granulocyte-macrophage colony-stimulating factor (GM-CSF), interleukin (IL)-1α, IL-1ß, IL-2, IL-3, IL-4, IL-6, IL-7, IL-10, IL-12, IL-13, IL-15, IL-18, tumor necrosis factor (TNF)-α, lymphotoxin (LT)-ß, TNF-related apoptosis inducing ligand (TRAIL), granulocyte colony-stimulating factor (G-CSF), macrophage colony-stimulating factor (M-CSF), macrophage migration-inhibitory factor (MIF), leukemia-inhibitory factor (LIF), T cell activator co-stimulators B7 (CD80) and B7-2 (CD86), Kit ligand and oncostatin M, and anti-angiogenic agents such as endostatin, angiostatin, kringle-1, kringle-2, kringle-3, kringle-4 and kringle-5.

[0035]

[31] The gene transfer carrier according to [27], wherein the protein that is useful for treatment of an anaerobic disease is a protein having an activity to convert a precursor of an antitumor substance to the antitumor substance.

[32] The gene transfer carrier according to [31], wherein the protein having an activity to convert a precursor of an antitumor substance to the antitumor substance is selected from the group consisting of cytosine deaminase, nitroreductase and ß-glucronidase.

[33] The gene transfer carrier according to [27], wherein the nucleic acid that is useful for treatment of an anaerobic disease is an siRNA associated with an anaerobic disease factor.

[0036]

[34] The gene transfer carrier according to [33], wherein the siRNA associated with an anaerobic disease factor is an siRNA associated with at least one tumor cell growth factor selected from the group consisting of fibroblast growth factor 2(FGF2),

endothelial cell growth factor (ECGF), vascular endothelial growth factor (VEGF) and hepatocyte growth factor (HGF).

[35] A pharmaceutical composition comprising the gene transfer carrier according to any one of [22] to [34].

[36] A DNA encoding a secretory signal peptide derived from *Bifidobacterium longum*.

[0037]

[37] The DNA encoding a secretory signal peptide according to [36], comprising a DNA sequence according to any one of the nucleotide sequences of SEQ ID No.: 6 to 28, or said sequence in which one or several nucleotide thereof are deleted, substituted or added.

[38] A secretory signal peptide encoded by the DNA according to [36] or [37].

[39] A transforming plasmid comprising the DNA according to [36] or [37].

[0038]

[40] The transforming plasmid according to [39], further comprising a DNA encoding a protein or nucleic acid that is useful for diagnosis or treatment of an anaerobic disease.

[41] The transforming plasmid according to [40], wherein the protein that is useful for diagnosis of an anaerobic disease is a fluorescent protein.

[42] The transforming plasmid according to [40], wherein the protein that is useful for treatment of an anaerobic disease is a protein having an antitumor activity.

[0039]

[43] The transforming plasmid according to [42], wherein the protein having an antitumor activity is one selected from the group consisting of cytokines such as interferon (IFN)-α, IFN-β, IFN-γ, granulocyte-macrophage colony-stimulating factor (GM-CSF), interleukin (IL)-1α, IL-1β, IL-2, IL-3, IL-4, IL-6, IL-7, IL-10, IL-12, IL-13, IL-15, IL-18, tumor necrosis factor (TNF)-α, lymphotoxin (LT)-β, TNF-related apoptosis inducing ligand (TRAIL), granulocyte colony-stimulating factor (G-CSF), macrophage colony-stimulating factor (M-CSF), macrophage migration-inhibitory factor (MIF), leukemia-inhibitory factor (LIF), T cell activator co-stimulators B7 (CD80) and B7-2

(CD86), Kit ligand and oncostatin M, and anti-angiogenic agents such as endostatin, angiostatin, kringle-1, kringle-2, kringle-3, kringle-4 and kringle-5.

[0040]

[44] The transforming plasmid according to [40], wherein the protein that is useful for treatment of an anaerobic disease is a protein having an activity to convert a precursor of an antitumor substance to the antitumor substance.

[45] The transforming plasmid according to [44], wherein the protein having an activity to convert a precursor of an antitumor substance to the antitumor substance is one selected from the group consisting of cytosine deaminase, nitroreductase and β-glucronidase.

[46] The transforming plasmid according to [40], wherein the nucleic acid that is useful for treatment of an anaerobic disease is an siRNA associated with an anaerobic disease factor.

[0041]

[47] The transforming plasmid according to [46], wherein the siRNA associated with an anaerobic disease factor is an siRNA associated with at least one tumor cell growth factor selected from the group consisting of fibroblast growth factor 2(FGF2), endothelial cell growth factor (ECGF), vascular endothelial growth factor (VEGF) and hepatocyte growth factor (HGF).

[48] A gene transfer carrier that is an anaerobic bacterium transformed with the transforming plasmid according to any one of [39] to [47].

[49] The gene transfer carrier according to [48], wherein the anaerobic bacterium is a *Bifidobacterium*.

[0042]

[50] The gene transfer carrier according to [49], wherein the *Bifidobacterium* is a species selected from the group consisting of *Bifidobacterium adolescentis*, *Bifidobacterium angulatum*, *Bifidobacterium animalis*, *Bifidobacterium asteroides*, *Bifidobacterium bifidum*, *Bifidobacterium boum*, *Bifidobacterium breve*, *Bifidobacterium catenulatum*, *Bifidobacterium choerinum*, *Bifidobacterium coryneforme*, *Bifidobacterium cuniculi*, *Bifidobacterium denticolens*, *Bifidobacterium dentium*, *Bifidobacterium gallicum*, *Bifidobacterium gallinarum*, *Bifidobacteria*

globosum, *Bifidobacteria indicum*, *Bifidobacterium infantis*, *Bifidobacteria inopinatum*, *Bifidobacterium lactis*, *Bifidobacterium lactentis*, *Bifidobacterium liberorum*, *Bifidobacterium longum*, *Bifidobacterium magnum*, *Bifidobacterium merycicum*, *Bifidobacterium minimum*, *Bifidobacterium mongoliense*, *Bifidobacterium parvulorum*, *Bifidobacterium pseudocatenulatum*, *Bifidobacterium pseudolongum*, *Bifidobacterium psychroaerophilum*, *Bifidobacterium pullorum*, *Bifidobacterium ruminale*, *Bifidobacterium ruminantium*, *Bifidobacterium saeculare*, *Bifidobacterium scardovii*, *Bifidobacterium subtile*, *Bifidobacterium suis*, *Bifidobacterium thermacidophilum* and *Bifidobacterium thermophilum*.

[0043]

[51] The gene transfer carrier according to [50], wherein the *Bifidobacterium* is *Bifidobacterium longum*.

[52] A pharmaceutical composition comprising the gene transfer carrier according to any one of [48] to [51].

[Effects of the Invention]

[0044]

The plasmid of the present invention is a novel plasmid useful for producing a transformed anaerobic bacterium for treating an anaerobic disease such as solid tumor, comprising an expression cassette having a secretory signal, and being a non-shuttle plasmid. The plasmid of the present invention does not comprise a replication origin that functions in a bacterium other than the transformed bacterium, and it is a non-shuttle plasmid which is not mutually replicated in both the transformant and other bacteria. It is therefore an extremely safe vector.

[0045]

Furthermore, the anaerobic bacterium transformed with the transforming plasmid of the present invention specifically colonizes and proliferates in an anaerobic disease tissue, and is capable of producing and secreting a protein or nucleic acid having a therapeutic activity for anaerobic disease, thereby being expected as a high-quality gene transfer carrier extremely useful as a therapeutic for an anaerobic disease.

Moreover, the novel secretory signal of the present invention is not only to be inserted into a plasmid, but also is to be incorporated directly into the genome of an anaerobic bacterium, allowing the production of a transformed anaerobic bacterium that is useful for treating an anaerobic disease.

[Brief Description of Drawings]

[0046]

[Fig. 1] Figure 1 is a map showing a summary of the construction of a secretory GFP-expressing plasmid (pSPxA-GFP).

[Fig. 2] Figure 2 is a map showing a summary of the construction of a secretory GFP-expressing plasmid (pSPxB-GFP).

[Fig. 3] Figure 3 is a map showing a summary of the construction of a secretory GFP-expressing plasmid (pSec2-GFP).

[Fig. 4] Figure 4 is a picture showing the results of western blotting of *B. longum* 105A/pSP3B-GFP, *B. longum* 105A/pSP7B-GFP, *B. longum* 105A/pSP23B-GFP, *B. longum* 105A/pSP7A-GFP and *B. longum* 105A/pSec2-GFP. In this figure, C indicates the lane for intracellular protein extract, T indicates the lane for the culture supernatant concentrate, and the numbers on the vertical axis indicates the molecular weight (kDa).

[0047]

[Fig. 5] Figure 5 is a map showing a summary of the construction of a secretory TNF alpha-expressing plasmid (pSPxA-TNF alpha).

[Fig. 6] Figure 6 is a map showing a summary of the construction of a secretory TNF alpha-expressing plasmid (pSPxB-TNF alpha).

[Fig. 7] Figure 7 is a map showing a summary of the construction of a secretory TNF alpha-expressing plasmid (pSec2-TNF alpha).

[Fig. 8] Figure 8 is a picture showing western blotting of *B. longum 105A*/pSP1B-TNF alpha, *B. longum 105A*/pSP3B-TNF alpha, *B. longum 105A*/pSP4B-TNF alpha, *B. longum 105A*/pSP7B-TNF alpha, *B. longum 105A*/pSP12B-TNF alpha, *B. longum 105A*/pSP16B-TNF alpha, *B. longum 105A*/pSP23B-TNF alpha, *B. longum 105A*/pSP7A-TNF alpha and *B. longum 105A*/pSec2-TNF alpha. In this figure, C

indicates the lane for intracellular protein extract, T indicates the lane for the culture supernatant concentrate, S indicates the lane for the culture supernatant and the numbers on the vertical axis indicates the molecular weight (kDa).

[0048]

[Fig. 9] Figure 9 is a picture showing the results of western blotting of *B. longum* 105A and *B. longum* 105A/pTNF3. The numbers on the vertical axis indicates the molecular weight (kDa).

[Fig. 10] Figure 10 is a map showing a summary of the construction of plasmid pBifi-SP3B-TNF alpha.

[Fig. 11] Figure 11 is a picture showing the results of western blotting of *Bifidobacterium longum* 105A/ pBifiSP3B-TNF alpha. The molecular weight markers of Lane 1 indicate, from the bottom, 20, 30, 40, 50, 60 and 80kDa, respectively.

[Fig. 12] Figure 12 is a map showing a summary of the construction of TNFα-expressing plasmid (pTNF3).

[0049]

[Fig. 13] Figure 13 is a map showing a summary of the construction of a mock plasmid (pBEshuttle) having a protein-expression cassette that does not comprise any insert.

[Fig. 14] Figure 14 is a graph showing the results of cytotoxicity assay for TNFα.

[Fig. 15] Figure 15 is a graph showing the results of chronological changes in tumor volume in an *in vivo* antitumor effect measurement assay in mouse for secretory TNFα-expressing plasmids *B. longum* 105A/pSP3B-TNF alpha and *B. breve*/pSP3B-TNF alpha.

[Fig. 16] Figure 16 is a graph showing the results of chronological changes in tumor volume in an *in vivo* antitumor effect measurement assay in mouse for secretory TNFα-expressing plasmids *B. longum* 105A/pSP3B-TNF alpha used in combination with adriamycin.

[Fig. 17] Figure 17 is a map showing a summary of the construction of a non-secretory human IL-18-expressing plasmid phIL18mut-His.

[Fig. 18] Figure 18 is a map showing a summary of the construction of a secretory human IL-18-expressing plasmid pSP3B-hIL18mut.

[Description of Embodiments]

[0050]

A non-shuttle plasmid used herein means a plasmid which comprises a replication origin that functions in the anaerobic bacterium to be transformed but does not comprises a replication origin that functions in other bacterium, and which is not mutually replicated in both the transformed anaerobic bacterium and a bacterium other than the transformed anaerobic bacterium.

The secretory signal used herein means a DNA fragment consisting of a nucleotide sequence encoding a secretory signal peptide (it may be referred to as a secretory signal peptide gene).

[0051]

Herein, a DNA encoding a protein having an antitumor activity, a DNA encoding a protein having an activity to convert a precursor of an antitumor substance to the antitumor substance, and a DNA encoding a protein having a therapeutic activity for an ischemic disease, etc. may collectively be referred to as "DNA encoding the protein of interest".

[0052]

An "siRNA" used herein is meant to include any of followings: an siRNA that is referred to as a small interfering RNA or a short interfering RNA, and a short hairpin RNA (shRNA) which is cleaved by an enzyme such as a Dicer within the target cell to generate an siRNA. It may also collectively refer to those including a modified siRNA and an siRNA complex.

[0053]

An "expression cassette" used herein refers to a set of genes for allowing the expression of certain protein or peptide fragment, and which comprises expression units such as a promoter, a gene encoding a protein to be expressed (target gene) and a terminator, and which may optionally further comprise other useful units. Other useful unit may include such as, for example, a gene encoding a signal peptide such as a secretory signal or a gene encoding a labeling protein.

[0054]

The present invention relates to a transforming plasmid for producing a transformed anaerobic bacterium, comprising an expression cassette comprising a secretory signal that functions in the anaerobic bacterium, and being a non-shuttle plasmid.

A transforming gene transfer carrier used for the treatment of a disease in which the disease site is in an anaerobic environment (hereinbelow referred to as an anaerobic disease) such as solid tumor or ischemic disease is required to be avirulent from the safety point of view.

Moreover, it is more preferred to be obligate anaerobic bacterium which colonizes and proliferates only in the disease tissue in an anaerobic condition, and neither colonizes nor proliferates in a normal tissue that is not in an anaerobic condition.

[0055]

The inventors previously studied on the method for treating malignant tumor using an obligate anaerobe *Bifidobacterium*, and developed *Bifidobacterium longum*105A transformed with a plasmid in which the gene of CD, an enzyme that converts a prodrug 5-FC to an antitumor substance 5-FU, has been incorporated (see Patent literatures 7 and 8).

It was confirmed that these transformed bifidobacteria specifically colonized and proliferated in an anaerobic disease tissue in a hypoxic condition upon being intravenously administered into a model animal of solid tumor, i.e., an anaerobic disease, whereas they quickly disappear in a normal tissue that is not in an anaerobic condition (see Non-patent literatures 1 and 2).

[0056]

Nevertheless, since the transformed bifidobacteria have been transformed using *E. coli* - *Bifidobacterium* shuttle plasmids such as pBLES100-S-eCD or pAV001-HU-eCD-M968, they might be replicated in *E. coli* when being horizontally transferred to *E. coli*.

Therefore, the inventors improved the plasmid in order to solve this problem and developed a non-shuttle plasmid pBifiCD which does not comprise a replication origin that functions in *E. coli* (see Patent literature 9).

[0057]

In methods for treating malignant tumor using these transformed bacteria, i.e., an enzyme-prodrug therapy (CD-5-FC therapy), it is desired that the antitumor substance 5-FU acts in tumor-tissue-specific manner in order to minimize its side effects. The inventors therefore transformed these transformed bifidobacteria using the plasmids none of which comprises a secretory signal, such that the expressed CD is not to be secreted from the bacteria cell but to convert intracellularly-incorporated 5-FC to 5-FU and export it from the bacteria cell, so that 5-FU exerts its antitumor activity only within tumor tissue.

[0058]

The bifidobacteria transformed with these plasmids without a secretory signal was characterized in that they colonize and proliferate specifically in an anaerobic disease tissue in an anaerobic condition and that the enzyme CD remains inside of the bacterium that colonizes and proliferates specifically in the anaerobic disease tissue. From these characteristics, the bifidobacteria has an advantage that they could avoid the systemic side-effect of antitumor substance 5-FU. On the other hand, a problem was also found that the 5-FU production is not equal to the CD production produced by the transformed *Bifidobacterium* but correlates to the amount of 5-FC uptake by the bacteria cell, thus the enzymatic function of the produced CD was not fully exerted.

[0059]

Moreover, in a case of a bacterium which produces not an enzyme that converts a prodrug such as CD to an antitumor substance but produces an antitumor protein or nucleic acid, it was necessary to destroy the cell after its expansion in the anaerobic disease tissue, in order to release the produced antitumor substance from the bacteria cell.

In order to solve these problems, the inventors started the development of a plasmid comprising a secretory signal that functions in an anaerobic bacterium, preferably an avirulent, obligate anaerobic bacterium, for allowing the secretion of the produced active substance, and the inventors developed a signal peptide useful for the production of said plasmid, which functions at least in the anaerobic bacterium and exhibits an excellent secretory effect of the expressed protein.

[0060]

Furthermore, in a method for treating such as solid tumor using a transformant gene transfer carrier, as mentioned above, it is also very important that the transforming gene in the gene transfer carrier to be used is not to be horizontally transferred to a pathogenic bacterium or an aerobic or facultative facultative anaerobic bacterium other than said gene transfer carrier, and that it is not to be replicated in that bacterium even if it was horizontally transferred.

Accordingly, said plasmid comprising a secretory signal is preferred to be a non-shuttle plasmid that does not have a replication origin that functions in an bacterium other than the transformed bacterium.

[0061]

The plasmid of the present invention is a plasmid for producing a transformed anaerobic bacterium, comprising an expression cassette comprising a secretory signal that functions at least in the anaerobic bacterium. Moreover, it is a non-shuttle plasmid, which does not comprise a replication origin that functions in a bacterium other than the transformed bacterium and which is not mutually replicated in both the transformant and other bacteria.

More specifically, it is a plasmid for producing a transformed anaerobic bacterium, which functions at least in *Bifidobacterium*, and which comprises an expression cassette having a secretory signal exhibiting an excellent secretory effect, and which does not comprises a replication origin that functions in a bacterium other than the transformed bacterium and which is not mutually replicated in both the transformant and other bacteria.

[0062]

The transforming plasmid of the present invention is characterized in that, by using this, it is able to produce a transformed anaerobic bacterium that is capable of expressing any protein or nucleic acid of interest and exerting an excellent and practical secretory function by the action of the secretory signal peptide contained in the expression cassette.

Moreover, the transforming plasmid of the present invention is characterized in that it is a non-shuttle plasmid vector which does not comprise a replication origin that

functions in a bacterium other than the transformed bacterium and which is not mutually replicated in both the transformant and other bacteria.

[0063]

To date, *Bifidobacterium adolescentis* amylase and *Bifidobacterium breve* Sec1, Sec2 and Sec3 for example have been reported as a signal peptide that functions in an anaerobic bacterium, especially in *Bifidobacterium*, and the plasmids with their secretory signals transferred therein have also been reported. However, in the bifidobacteria transformed with these plasmid, the expected secretion of the protein of interest was small.

[0064]

Moreover, no GFP-secreting function was exhibited in *Bifidobacterium longum* transformed using a plasmid produced by cloning the secretory signal and promoter regions of the *Bifidobacterium adolescentis* amylase and incorporating these with a gene encoding an UV-optimized green fluorescent protein mutant (GFPuv: CLONTECH Laboratories, Inc.), when being confirm its secreting function of an expressed protein (GFP), assuming that this secretory signal peptide does not afford secreting any protein of interest.

[0065]

Furthermore, previously reported plasmid vectors for producing transformed anaerobic bacteria which extracellularly secrete the expressed protein are shuttle plasmids made by fusing a plasmid derived from *E. coli* to a plasmid derived from the transformed bacterium, which function both in *E. coli* and the transformed bacteria. No report has been made on a transforming plasmid which functions only in the transformed bacterium other than *E. coli*.

[0066]

As a secretory signal peptide that functions in an anaerobic bacterium comprised by the transforming plasmid of the present invention, any secretory signal peptide may be used as long as it functions at least in the anaerobic bacterium, although those which function in *Bifidobacterium* are preferred. In view of the toxicity to the transformed bacterium and functionality, a secretory signal peptide derived from *Bifidobacterium* is more preferred, and a secretory signal peptide derived

from *Bifidobacterium longum* is further preferred. Examples of secretory signals derived from *Bifidobacterium longum* include, for example, a secretory signal peptide encoded by a DNA expressed by any one of the nucleotide sequences of SEQ ID No.: 6 to 28, or said sequence in which one or several nucleotide thereof are deleted, substituted or added. Among these, a secretory signal peptide encoded by a DNA expressed by the nucleotide sequence of SEQ ID No.: 6, 7, 8, 9, 12, 14, 15, 17, 21, 25 or 28, or said sequence in which one or several nucleotide thereof are deleted, substituted or added is preferred, and a secretory signal peptide encoded by a DNA expressed by the nucleotide sequence of SEQ ID No.: 8 or 25, or said sequence in which one or several nucleotide thereof are deleted, substituted or added is most preferred.

[0067]

Furthermore, a promoter in the expression cassette comprised in the transforming plasmid of the present invention may be any promoter as long as it functions in an anaerobic bacterium and functions as a promoter of the secretory signal peptide. Examples include such as a promoter adjacent to the upstream of a secretory signal peptide derived from *Bifidobacterium* (promoter X), or a promoter of a gene encoding a histone-like DNA binding protein that functions in *Bifidobacterium* (HU promoter). Specifically, a promoter encoded by a DNA of a promoter region of the nucleotide sequence expressed by any one of SEQ ID No.: 29 to 44, and a DNA of the nucleotide sequence expressed by any one of SEQ ID No.: 45 or said nucleotide sequence in which one or several nucleotide thereof are deleted, substituted or added is included. Among these, a promoter or HU promoter encoded by a DNA of a promoter region of the nucleotide sequence expressed by SEQ ID No.: 35 or a single nucleotide polymorphism thereof is preferred, and a HU promoter is more preferred, and a promoter encoded by a DNA expressed by the nucleotide sequence of SEQ ID No.: 45 or said sequence in which one or several nucleotide thereof are deleted, substituted or added is most preferred.

[0068]

Furthermore, a terminator comprised in the transforming plasmid of the present invention may be any terminator as long as it functions in *Bifidobacterium* and functions as a terminator of a secretory signal peptide, although a terminator of a gene

encoding a histone-like DNA binding protein that functions in *Bifidobacterium* (HU terminator) is preferred, and in particular, a DNA expressed by the nucleotide sequence of SEQ ID No.: 46 or said sequence in which one or several nucleotide thereof are deleted, substituted or added is most preferred.

[0069]

A "single nucleotide mutant" herein means a single nucleotide polymorphism in which at least one nucleotide has been mutated (hereinbelow referred to as SNPs), including a SNP at one site as well as SNPs at several sites. Accordingly, it is interchangeable with a "sequence in which one or several nucleotide thereof are deleted, substituted or added".

[0070]

As a gene encoding a protein or nucleic acid of interest to be secreted (i.e., a target gene) comprised in the transforming plasmid of the present invention, any gene may be used such as a gene encoding a fluorescent protein, a gene encoding a protein having an antitumor activity, a gene encoding a protein having a therapeutic activity for an ischemic disease and a gene encoding a protein having an activity to convert a precursor of an antitumor substance to the antitumor substance.

A fluorescent protein includes such as green fluorescent protein (GFP) and red fluorescent protein (RFP) of various types.

[0071]

A protein having an antitumor activity includes, for example, a cytokine, and the examples of specific cytokines include such as interferon (IFN)-α, ß, γ, granulocyte-macrophage colony-stimulating factor (GM-CSF), interleukin (IL)-1α, 1ß, 2, 3, 4, 6, 7, 10, 12, 13, 15, 18, tumor necrosis factor (TNF)-α, lymphotoxin (LT)-ß, TNF-related apoptosis inducing ligand (TRAIL), granulocyte colony-stimulating factor (G-CSF), macrophage colony-stimulating factor (M-CSF), macrophage migration-inhibitory factor (MIF), leukemia-inhibitory factor (LIF), T cell activator co-stimulators B7 (CD80) and B7-2 (CD86), Kit ligand, oncostatin M.

It also includes anti-angiogenic agents such as endostatin, angiostatin, kringle-1, 2, 3, 4 and 5.

[0072]

Proteins having an activity to convert a precursor of an antitumor substance to the antitumor substance may include such as cytosine deaminase (hereinbelow referred to as CD), i.e., an enzyme that converts 5-florocytosine (hereinbelow referred to as 5-FC) to an antitumor active substance 5-fluorourasil (hereinbelow referred to as 5-FU); nitroreductase, i.e., an enzyme that converts 5-aziridino-2,4-dinitrobenzamide (hereinbelow referred to as CB1945) to an antitumor active alkylating agent; herpes simplex virus type 1 thymidine kinase (hereinbelow referred to as HSV1-TK), i.e., an enzyme that convert gancyclovir to an antitumor active metabolite; and ß-glucronidase, i.e., an enzyme that convert a glucronate-conjugated antitumor active substance to the antitumor active substance.

[0073]

Moreover, proteins having a therapeutic activity for an ischemic disease may include a protein having a proangiogenic activity useful for treating an ischemic disease. Specifically it may include such as fibroblast growth factor 2 (FGF2), endothelial cell growth factor (ECGF), vascular endothelial growth factor (VEGF) and hepatocyte growth factor (HGF).

The sequences of these proteins are known in various organisms, and a DNA encoding the protein of interest may be obtained by utilizing known procedures such as PCR methods and artificial gene synthesis, based on the sequence information thereof.

[0074]

A nucleic acid having a therapeutic activity for a disease in an anaerobic environment may include an siRNA associated with an anaerobic disease factor. More specifically, siRNAs directed to tumor cell growth factors such as fibroblast growth factor 2(FGF2), endothelial cell growth factor (ECGF), vascular endothelial growth factor (VEGF) and hepatocyte growth factor (HGF) may be included.

Similarly, the sequences of these nucleic acids are known and can be obtained by utilizing known procedures such as PCR methods based on the sequence information thereof.

[0075]

The plasmid of the present invention may be produced, for example, as follows:

A shuttle plasmid may be produced, for example, according to the routine procedures, by inserting into a shuttle plasmid having a replication origin that functions in each of a transformant and other bacteria (e.g., *E. coli*) a secretory signal that functions at least in *Bifidobacterium* and its promoter gene, and, in their downstream, at least one gene or nucleic acid encoding a desired protein useful for diagnosis or treatment of an anaerobic disease (target gene), and, in further downstream, a terminator gene of the secretory signal peptide that functions in the anaerobic bacterium.

[0076]

Furthermore, if desired, the replication origin of the bacterium other than the transformed bacterium may be removed from this shuttle plasmid to produce a non-shuttle plasmid.

The operation in each step may be performed in accordance with known method as described in literatures.

The gene transfer carrier for treating an anaerobic disease of the present invention may be produced by transforming any anaerobic bacterium to be transformed using said transforming plasmid of the present invention, according to known methods in the art of genetic engineering.

[0077]

Because the anaerobic bacterium transformed with a transforming plasmid of the present invention is to be used for a therapeutic agent for an anaerobic disease such as solid tumor, it must be an obligate anaerobic and avirulent. Thus, it may be a virulent bacterium such as *Clostridium* or *Salmonella* that has been made avirulent, or it may be a facultative anaerobic bacterium such as *Lactobacillus* that has been mutated to an obligate anaerobic.

Preferably it includes an avirulent anaerobic bacterium, more preferably an avirulent enterobacterium, and among those *Bifidobacterium* is most preferred.

[0078]

Bifidobacterium includes, for example, *Bifidobacterium adolescentis*, *Bifidobacterium angulatum*, *Bifidobacterium animalis*, *Bifidobacterium asteroides*, *Bifidobacterium bifidum*, *Bifidobacterium boum*, *Bifidobacterium breve*,

Bifidobacterium catenulatum, *Bifidobacterium choerinum*, *Bifidobacterium coryneforme*, *Bifidobacterium cuniculi*, *Bifidobacterium denticolens*, *Bifidobacterium dentium*, *Bifidobacterium gallicum*, *Bifidobacterium gallinarum*, *Bifidobacteria globosum*, *Bifidobacteria indicum*, *Bifidobacterium infantis*, *Bifidobacteria inopinatum*, *Bifidobacterium lactis*, *Bifidobacterium lactentis*, *Bifidobacterium liberorum*, *Bifidobacterium longum*, *Bifidobacterium magnum*, *Bifidobacterium merycicum*, *Bifidobacterium minimum*, *Bifidobacterium mongoliense*, *Bifidobacterium parvulorum*, *Bifidobacterium pseudocatenulatum*, *Bifidobacterium pseudolongum*, *Bifidobacterium psychroaerophilum*, *Bifidobacterium pullorum*, *Bifidobacterium ruminale*, *Bifidobacterium ruminantium*, *Bifidobacterium saeculare*, *Bifidobacterium scardovii*, *Bifidobacterium subtile*, *Bifidobacterium suis*, *Bifidobacterium thermacidophilum*, *Bifidobacterium thermophilum*, and *Bifidobacterium longum* is most preferred.
[0079]

These bacteria are all commercially available or readily available from a depository organization. For example, those such as *Bifidobacterium longum* ATCC-15707, *Bifidobacterium bifidum* ATCC-11863 and *Bifidobacterium infantis* ATCC-15697 can readily be obtained from ATCC (The American Type Culture Collection).

Strains of each bacterium are not particularly limited. For example, strains of *Bifidobacterium longum* may include strains of *Bifidobacterium longum* 105-A, *Bifidobacterium longum* aE-194b, *Bifidobacterium longum* bs-601 and *Bifidobacterium longum* M101-2, among which *Bifidobacterium longum* 105-A strain is preferred.
[0080]

Strains of *Bifidobacterium breve* may include for example *Bifidobacterium breve* standard strain (JCM1192), *Bifidobacterium breve* aS-1 and *Bifidobacterium breve* I-53-8W strains, among which *Bifidobacterium breve* standard strain and *Bifidobacterium breve* aS-1 strain are preferred.

Strains of *Bifidobacterium infantis* may include for example *Bifidobacterium infantis* standard strain (JCM1222) and *Bifidobacterium infantis* I-10-5 strain, among which *Bifidobacterium infantis* standard strain and *Bifidobacterium infantis* I-10-5 strain are preferred.

[0081]

Strains of *Bifidobacterium lactentis* may include for example *Bifidobacterium lactentis* standard strain (JCM1210).

The gene transfer carrier of the present invention is a gene transfer carrier consisting of said anaerobic bacterium transformed with the transforming plasmid of the present invention, being capable of growing in a tissue in an anaerobic environment, and being capable of expressing a protein having an activity of interest, and having no possibility of being horizontally transferred to a pathogenic or aerobic or facultative anaerobic bacterium other than the transformed bacterium.

[0082]

The production of the gene transfer carrier of the present invention may be carried out according to methods described in commercially available experiment protocols such as "IDENSHI MANUAL" (Kodan-sha), "IDENSHI-SOUSA JIKKEN HOU", Y. Takagi ed., (Kodan-sha), " Molecular Cloning", Cold Spring Harbor Laboratory, 1982, "Molecular C1oning", 2nd ed., Cold Spring Harbor Laboratory, 1989 and Methods in Enzymol., 194, 1991.

[0083]

The pharmaceutical composition of the present invention is not particularly limited as long as it comprises a gene transfer carrier of the present invention. Also, the therapeutic agent of the present invention for an anaerobic disease is not particularly limited as long as it comprises a gene transfer carrier of the present invention.

Also, the pharmaceutical composition or therapeutic agent for an anaerobic disease of the present invention may comprise two or more of the gene transfer carriers of the present invention.

[0084]

Moreover, the pharmaceutical composition or therapeutic agent for an anaerobic disease of the present invention may be used in combination with a pharmaceutical composition or therapeutic agent for the anaerobic disease comprising a compound exhibiting a therapeutic effect for the anaerobic disease other than the gene transfer carrier of the present invention.

Moreover, the pharmaceutical composition or therapeutic agent for an anaerobic disease of the present invention may comprise an optional ingredient other than the gene transfer carrier of the present invention as long as it does not interfere with the effect of the present invention. Such optional ingredient includes for example such as a pharmacologically acceptable carrier, excipient or diluent.

[0085]

The dosage form of the pharmaceutical composition or therapeutic agent for an anaerobic disease of the present invention is not particularly limited, and may include, for example, a liquid or solid formulation comprising a gene transfer carrier of the present invention. A liquid may be produced by purifying the culture medium of an anaerobic bacterium of the gene transfer carrier of the present invention, adding thereto an appropriate physiological saline or fluid replacement or pharmaceutical additives as required, then filling it into an ample or vial. A solid formulation may be produced by adding into a liquid an appropriate protective agent and filling it into an ample or vial before lyophilizing or L-drying it, or by adding into a liquid an appropriate protective agent and lyophilizing or L-drying it before filling it into an ample or vial. Method for administrating the pharmaceutical composition or therapeutic agent for an anaerobic disease of the present invention may be either oral or parenteral administration, although parenteral administration is preferred, such as, for example, an intravenous injection, subcutaneous injection, topical infusion or intraventricular administration, and an intravenous injection is most preferred.

[0086]

A dosage of gene transfer carrier of the pharmaceutical composition or therapeutic agent for an anaerobic disease of the present invention is not particularly limited as long as it is an amount sufficient to allow the growth in a disease site and the expression of the active protein of a therapeutically effective amount, although, in view of cost and avoiding the side effects as much as possible, it is preferred to be as small as possible within a range such that a desired therapeutic effect can be achieved.

A dosage of gene transfer carrier of the pharmaceutical composition or therapeutic agent for an anaerobic disease of the present invention may appropriately be selected according to the severity of the disease, the body weight, age and sex of the

patient, and may appropriately be increased or decreased according to the level of improvement.

[0087]

For instance, when a therapeutic agent of the present invention for an anaerobic disease is used as a therapeutic agent for solid tumor, the dosage is set with respect to such as the antitumor activity of the anaerobic bacterium itself to be used, the type of the protein having an antitumor activity produced by the anaerobic bacterium to be used, the therapeutically effective amount of the antitumor substance converted from the antitumor substance precursor, and the production of the active protein by the anaerobic bacterium to be used.

[0088]

In specific, in the case of an intravenous administration, for example, it is particularly desired to decrease the risk of embolization by bacterial mass. Therefore, a preference is given to either a plurality of separate injection of an injectable formulation at a concentration as low as possible, or a continuous infusion of a dilution with an appropriate fluid replacement. For example, in an adult, the bacterial cells of the anaerobic bacterium of the invention are administered at 10^6 to 10^{12} cfu per 1kg of the body weight, once to several times per day, for one to several days, either continuously or with appropriate intervals. More specifically, 1 to 1000 mL per an adult of a formulation containing the bacterial cells of *Bifidobacterium* of the invention at 10^4 to 10^{10} cfu/mL is administered, either directly or in dilution with an appropriate fluid replacement, once to several times per day, for one to several days.

[0089]

In case of a topical administration for direct administration to a disease tissue, it is desired that the bacteria colonizes and proliferate throughout the disease tissue as broadly as possible. Therefore, it is desired to administer an injection at a high concentration to a plurality of sites in the disease tissue. For example, in an adult, the bacterial cells of *Bifidobacterium* of the invention are administered at 10^6 to 10^{12} cfu per 1kg of the body weight, once to several times per day, for one to several days as required, either continuously or with appropriate intervals. More specifically, 1 to 1000 mL per an adult of a formulation containing the bacterial cells of *Bifidobacterium*

of the invention at 10^4 to 10^{10} cfu/mL is administered, several times per day, for one to several continuous days as required.

[0090]

If the loss of bacteria is confirmed during the treatment period, the treatment is temporally suspended, and bacteria are administered as above.

A "combination of X and Y" herein encompasses both cases in which X and Y are in different forms and in which X and Y are in the same form (for example, a form comprising X and Y). In the case in which X and Y are in different forms, either of X and Y may further comprise other ingredients.

[0091]

The pharmaceutical composition or therapeutic agent for an anaerobic disease of the present invention may be applied to a disease in an anaerobic environment, preferable to various solid tumors. Solid tumor may include such as, for example, colorectal cancer, brain tumor, head and neck cancer, breast cancer, lung cancer, esophageal cancer, gastric cancer, liver cancer, gallbladder cancer, bile duct cancer, pancreatic cancer, pancreatic islet cell carcinoma, choriocarcinoma, colon cancer, renal cell carcinoma, adrenocortical cancer, bladder cancer, testicular cancer, prostate cancer, testicular tumor, ovarian cancer, uterine cancer, choriocarcinoma, thyroid cancer, malignant carcinoid tumor, skin cancer, malignant melanoma, osteosarcoma, soft tissue sarcoma, neuroblastoma, Wilms' tumor, retinoblastoma, melanoma and squamous cell carcinoma.

[0092]

Other diseases in an anaerobic environment may include such as, for example, ischemic diseases such as myocardial infarction or arteriosclerosis obliterans, or lower limb ischemic diseases such as Buerger's disease.

The present invention also encompasses a novel secretory signal peptide useful in particular for a use in foregoing plasmid, gene transfer carrier or pharmaceutical composition. The inventors first performed a genomic analysis of *Bifidobacterium longum* 105A which is a parent strain of foregoing transformed *Bifidobacterium*, in order to discover a secretory signal peptide that functions in *Bifidobacterium* and exerts an excellent secretory effect of the expressed protein. The inventors then chose

25 proteins which had a secretory signal but not have a transmembrane region, therefore being assumed to be secretory proteins. Of the 25 proteins, 16 had a secretory signal adjacent to a promoter, whereas 9 had a secretory signal not adjacent to a promoter.

[0093]

The nucleotide sequences of the coding region of the 25 proteins were investigated. The regions expected to be secretory signals and promoters were cloned, as described below, for 22 secretory proteins (Nos. 1-16, 19, 21-25) out of 25 excluding 3 (Nos. 17, 18 and 20) which were assumed to be defective protein coding sequences (CDSs).

[0094]

For 16 proteins in which a secretory signal is adjacent to a promoter, the regions expected to be the promoter (promoter X) and secretory signal (hereinbelow referred to as SPxA) were cloned and combined to a gene encoding UV-optimized green fluorescent protein mutant (GFPuv; CLONTECH Laboratories, Inc.) and a terminator of histone-like peptide (HU) of *Bifidobacterium* used in plasmid production described in Patent literatures 7 to 9 above to generate a plasmid, and the secretory function of the expressed protein (GFP) was confirmed for *Bifidobacterium* transformed with the plasmid (pSPxA).

[0095]

Also, for all 22 proteins including the 9 rest proteins in which a secretory signal is not adjacent to a promoter, the secretory signal regions not including promoters (hereinbelow referred to as SPxB) were cloned and combined to a promoter of histone-like peptide (HU) of *Bifidobacterium* above, a gene encoding green fluorescent protein and the terminator of histone-like peptide (HU) of *Bifidobacterium* above (HU terminator) to generate a plasmid, and the secretory function of the expressed protein (GFP) was confirmed for *Bifidobacterium* transformed with the plasmid (pSPxB) as described above.

[0096]

The results confirmed that 12 plasmids (pSP7A-GFP, pSP12A-GFP, pSP1B-GFP, pSP2B-GFP, pSP3B-GFP, pSP4B-GFP, pSP7B-GFP, pSP9B-GFP,

pSP10B-GFP, pSP12B-GFP, pSP16B-GFP, and pSP23B-GFP) showed secreting tendency, and 4 plasmids (pSP7A-GFP, pSP3B-GFP, pSP7B-GFP, and pSP23B-GFP) demonstrated an excellent secreting function of the expressed protein.

[0097]

Furthermore, in the genomic analysis of the *Bifidobacterium longum* 105A, a search was made for a protein showing a nucleotide sequence with a high homology at amino acid level to Sec2 gene whose secretion in *Bifidobacterium breve* has been reported (Laura E. MacConaill et al., Applied and Environmental Microbiology, 2003 Vol. 69: pp6994-7001), and its secretory signal peptide was also investigated. Namely, a gene encoding said secretory signal peptide was cloned in combination with a promoter of histone-like peptide (HU) of *Bifidobacterium* above (HU promoter), and combined with a gene encoding green fluorescent protein (GFP) and the terminator of histone-like peptide (HU) of *Bifidobacterium* above (HU terminator) to generate a plasmid, and the secretory function of the expressed protein (GFP) was confirmed for *Bifidobacterium* transformed with the plasmid (pSec2-GFP) as described above, confirming an excellent secreting function of the expressed protein.

[0098]

Next, for 13 plasmids whose secreting tendency was confirmed above, plasmids in which the gene encoding GFP was replaced with an insert of a gene encoding human TNF-α, another protein of interest, which were then used to transform *Bifidobacterium* and their function to secrete the expressed protein was confirmed.

The results confirmed that 9 plasmids (pSP7A-TNFα, pSP1B-TNFα, pSP3B-TNFα, pSP4B-TNFα, pSP7B-TNFα, pSP12B-TNFα, pSP16B-TNFα, pSP23B-TNFα, and pSec2B-TNFα) showed secreting function, and 2 plasmids (pSP3B-TNFα, pSP23B-TNFα) demonstrated particularly good secreting function of the expressed protein.

[0099]

Furthermore, from these plasmids, plasmids in which replication origins that function in bacteria other than *Bifidobacterium*, e.g., pUC Ori, were removed were generated. These plasmid was used for transforming *Bifidobacterium* and their secreting function of the expressed protein was confirmed. It was confirmed that the

plasmids in which pUC Ori, a replication origin that functions in bacteria other than *Bifidobacterium*, has been removed could also exert a similarly excellent secreting function of the expressed protein.

[0100]

Accordingly, the inventors discovered a novel secretory signal peptide which functions at least in *Bifidobacterium* and which exhibits an excellent secreting function of the expressed protein.

As mentioned above, the secretory signal peptide of the invention has an excellent secretory activity, and functions in *Bifidobacterium*, an avirulent, obligate anaerobic bacterium, and is therefore particularly suitable for a use in the plasmid, gene transfer carrier or pharmaceutical composition described above. Accordingly, the plasmid, gene transfer carrier or pharmaceutical composition described above in any embodiment comprising the novel secretory signal peptide of the present invention are also encompassed in the present invention.

[Examples]

[0101]

Hereinbelow, the present invention is illustrated more specifically by production examples and working examples, although the technical scope of the present invention is not to be limited by these examples.

[0102]

Reference Example 1: in Silico Screening of Secretory Signals

For 1941 amino acid sequences in entire translational region predicted from the whole genome sequence of *Bifidobacterium longum* 105A, signal peptides prediction using PrediSi was performed and 188 signal peptides were predicted. The prediction employed a parameter set for Gram Positive Bacteria.

Among the 188 signal peptides predicted, 25 which did not have a transmembrane region were chosen as secretory protein candidates. Their putative secretory protein coding regions are shown in Table 1.

[0103]

Table 1　Positions and directions of secretory protein candidates in the genome

Candidate No.	Operon	Position, direction
1	head	20020 -> 20982
2	head	762462 -> 763787
3	head	781649 -> 782512
4	head	842877 -> 844577
5	head	1433216 -> 1433650
6	head	1662965 -> 1664209
7	head	1917150 -> 1917836
8	head	164213 <- 165142
9	head	636847 <- 637464
10	head	752108 <- 752839
11	head	839663 <- 841006
12	head	1201317 <- 1202642
13	head	1744372 <- 1744605
14	head	1958176 <- 1958493
15	head	2225694 <- 2227349
16	head	2258216 <- 2258665
17	not head	58769 -> 59881
18	not head	471365 -> 472411
19	not head	768637 -> 768834
20	not head	695274 <- 696701
21	not head	708157 <- 708966
22	not head	930317 <- 931657
23	not head	1115148 <- 1116155
24	not head	1326094 <- 1327137
25	not head	1867821 <- 1868807

[0104]

Production Example 1: Construction of a Secretory GFP-expressing Plasmid (pSPxA-GFP)

We constructed a plasmid that expresses secretory GFP by a promoter of a signal peptide candidate. A summary is shown in Fig. 1. Details are provided below.

[0105]

Insert Preparation

Among the 25 secretory protein candidates, for 16 whose gene are located on the head of the operon (Table 1, Nos. 1 to 16), putative signal peptide portions comprising a promoter and 60 to 90 nucleotides downstream thereof were amplified by PCR method as described below.

Forward primers were designed 300bps upstream of the translation start site and reverse primers were designed 60 to 90 bps downstream of the DNAs encoding the signal peptides. 30ng of the genomic DNA of *Bifidobacterium longum* 105A was used as template for PCR using 2 x Phusion Flash PCR Master mix (FINNZYMES).

[0106]

The PCR program was as follows: 98°C for 10 seconds, then 30 cycles of 98°C for 1 second plus 55°C for 5 seconds plus 72°C for 9 seconds, and 72°C for 1 minute. PCR primers for each signal peptide are shown in Table 2.1. 15 nucleotides on 5' side of each primer have a homologous sequence to those of the vectors shown below.

[0107]

Table 2.1 Primers for amplification of signal peptides (SPxA)

No.	Primer Name	Sequence (5' -> 3')	PCR product name
1	SP1_F1_primer	cttttctacggatccTCTCGTGTACGCGAATACG	SP1A
	SP1_R1_primer	ctcctcgcccttggaTTCCACGCGCTCCTTGG	
2	SP1_F2_primer	cttttctacggatccCGCGCTGCAATGGCGTCGG	SP2A
	SP1_R2_primer	ctcctcgcccttggaCAAAAACAGCACGCGGGTG	
3	SP1_F3_primer	cttttctacggatccGGCGTCTGGCAGCGCACAG	SP3A
	SP1_R3_primer	ctcctcgcccttggaGGCGATGGTCAGCTTGC	

4	SP1_F4_primer	cttttctacggatccATCAGAGGAGCCGGTGC	SP4A
	SP1_R4_primer	ctcctcgcccttggaGCCGAACAGACGCGGGGG	
5	SP1_F5_primer	cttttctacggatccCTCGCGGGCTTGGCGGTC	SP5A
	SP1_R5_primer	ctcctcgcccttggaTTGGTCGATGATGGCCTTG	
6	SP1_F6_primer	cttttctacggatccGTTCGGGTCCGGGTGCGG	SP6A
	SP1_R6_primer	ctcctcgcccttggaATCGACAATAGGACTTTTCC	
7	SP1_F7_primer	cttttctacggatccAGGCGGTCCATGGTGGATG	SP7A
	SP1_R7_primer	ctcctcgcccttggaGGTGGAGGTGGATTCGG	
8	SP1_F8_primer	cttttctacggatccAACCATTCGGACGCGCAG	SP8A
	SP1_R8_primer	ctcctcgcccttggaCATCGTTGCCTCGCCCG	
9	SP1_F9_primer	cttttctacggatccCCAGGGCCCGAAGGAAGAG	SP9A
	SP1_R9_primer	ctcctcgcccttggaGACGATCTGATGCGCCAGC	
10	SP1_F10_primer	cttttctacggatccCAGCCCATCGCTATGGAG	SP10A
	SP1_R10_primer	ctcctcgcccttggaTCGCTGCTTGAGTTTGCCG	
11	SP1_F11_primer	cttttctacggatccTCTGTAGCGGGAGGTTGCG	SP11A
	SP1_R11_primer	ctcctcgcccttggaCAGCGTGGGCTCCCAAGCC	
12	SP1_F12_primer	cttttctacggatccGCGTTACTTCCATGTTCGC	SP12A
	SP1_R12_primer	ctcctcgcccttggaGGAACGGGTCCACAGGGTG	
13	SP1_F13_primer	cttttctacggatccCCTTCTCAACGCCAGCGGC	SP13A
	SP1_R13_primer	ctcctcgcccttggaAGACTCGCTAGCACAGCAC	
14	SP1_F14_primer	cttttctacggatccGACATAGCGCGGTTTCATACC	SP14A
	SP1_R14_primer	ctcctcgcccttggaTTGGGCCACTATTGTCTTC	
15	SP1_F15_primer	cttttctacggatccACCGGCACCTGCGCCGGCG	SP15A
	SP1_R15_primer	ctcctcgcccttggaCTTGCCTGAGGCATCTTG	
16	SP1_F16_primer	cttttctacggatccATCGCAACACCTCCATATTGTTCC	SP16A
	SP1_R16_primer	ctcctcgcccttggaGGCCAACGGAGTCGTCTCG	

[0108]

Analyses of a part of PCR product using 2% agarose gel (1 x TBE buffer, with ethidium bromide) confirmed a single band of putative size.

When a single band was not confirmed, annealing temperature was changed from 55°C to 60°C and performed PCR once more.

PCR products were purified using PCR product purification kit (QIAquick PCR purification kit, QIAGEN) and purified PCR products were quantified by absorption photometer.

A signal peptide fragment comprising its own promoter region is named as a signal peptide xA (SPxA) (x=1 to 16).

[0109]

Vector Preparation

Vectors for cloning SPxA were prepared as follows. A summary of the preparation is shown in Fig. 1. Plasmid pAmyB-GFPuv vector (Fig. 1, top panel, right figure; SEQ ID No.: 1) was completely digested with BamHI and Eco147I (both from Fermentas). Reacting condition was in accordance with the instruction for use of the enzymes. Digested plasmid was fractioned by electrophoresis on 0.8% agarose gel for purification (1 x TBE buffer, with ethidium bromide), a large fragment of approximately 4.2 kbps was cut out, and DNA was extracted from agarose and purified using DNA extraction kit from a gel (QIAquick Gel Extraction Kit, QIAGEN). Purified DNA fragment (vector) was electrophoresed on 0.8% agarose gel (1 x TBE buffer, with ethidium bromide) with a DNA concentration marker to estimate its concentration.

For GFPuv coding sequence in pAmyB-GFPuv vector, codons have been optimized (GenScript) for *Bifidobacterium*.

[0110]

Recombination Reaction

The vector and insert prepared above were mixed in 1: 3 to 10 molar ratio, and linked by recombination reaction (CloneEZ Kit, GenScript). Reacting conditions were in accordance with the product instruction.

[0111]

Transformation of *E. coli*

E. coli TOP10 chemically Competent Cell (Life Technologies Japan) was transformed using 2μL of the recombination reaction solution above, smeared onto a LB (containing 75μg/mL spectinomycin) plate and cultured overnight at 37°C. Transforming conditions were in accordance with the product instruction.

The transformed *E. coli* colonies were cultured overnight in a LB (containing 75μg/mL spectinomycin) liquid medium at 37°C, and plasmid was extracted from the culture (QIAprep Spin Miniprep Kit, QIAGEN). The insert sequence in this plasmid was determined, and the plasmid was named as pSPxA-GFP (x=1 to 16).

[0112]

Transformation of *Bifidobacterium*

3 to 5 μL of the plasmid DNA extracted from transformed *E. coli* above was used for transforming *Bifidobacterium longum* 105A by electroporation system (Gene Pulser II, Bio-Rad Laboratories). Immediately after an electric shock, a mixture of 800μL of IMR liquid medium and 50μL of vitamin C additive solution was added to the cuvette, which was then collected in a sterilized 2mL microtube. Similar manipulation was performed for each tube, before loosening the lid of these 2mL tubes and placing in a dessicator. The dessicator was deaerated by a vacuum pump and filled with carbon dioxide. This manipulation was repeated three times to replace the air in the dessicator with carbon dioxide, before placing the dessicator in an incubator set to 37°C and incubating for 3 hours.

[0113]

After the incubation, each bacterial suspension was mixed thoroughly, and 100μL thereof was measured and smeared to two IMR agar media (containing 75μg/mL SPCM). These plates were placed in a sealed vessel with deoxygenating/carbon dioxide-generating agent (Anaero Pac®-Anaero, MITSUBISHI GAS CHEMICAL, INC.) and cultured for two days in an incubator set to 37°C.

[0114]

Production Example 2: Construction of a Secretory GFP-expressing Plasmid (pSPxB-GFP)

A plasmid that expresses secretory GFP by histone-like promoter (HU promoter) of *Bifidobacterium*. A summary is shown in Fig. 2. Details are given below.

[0115]

Insert Preparation

Among the 25 secretory protein candidates above, for 22 candidates (Nos. 1-16, 19, 21-25) excluding 3 (Nos. 17, 18, 20) that were assumed to be deficient protein coding sequences, DNA fragments containing the putative signal peptide coding parts and 60 to 90 nucleotides downstream thereof were amplified by PCR.

Forward primers were designed at the translation start site and reverse primers were designed at 60 to 90 nucleotides downstream of the DNA encoding the signal peptides. PCR primers for each signal peptide are shown in Table 2.2. 15 nucleotides at 5' side of each primer have a homologous sequence to the vector shown below.

[0116]+[0117]

Table 2.2 Primers for amplification of signal peptides (SPx)

	Primer Name	Sequence (5' -> 3')	PCR product
1	SP1_F2_primer	caagaaggatgctttATGGCGGAAACTACCGTTAAGC	SP1
	SP1_R1_primer	ctcctcgcccttggaTTCCACGCGCTCCTTGG	
2	SP2_F2_primer	caagaaggatgctttGTGGGTATGACTGAGAACG	SP2
	SP1_R2_primer	ctcctcgcccttggaCAAAAACAGCACGCGGGTG	
3	SP3_F2_primer	caagaaggatgctttATGTTCAATAAGCGACAC	SP3
	SP1_R3_primer	ctcctcgcccttggaGGCGATGGTCAGCTTGC	
4	SP4_F2_primer	caagaaggatgctttATGACCACTCACAACAGC	SP4
	SP1_R4_primer	ctcctcgcccttggaGCCGAACAGACGCGGGGG	
5	SP5_F2_primer	caagaaggatgctttATGACCGCGATTGACGAG	SP5
	SP1_R5_primer	ctcctcgcccttggaTTGGTCGATGATGGCCTTG	
6	SP6_F2_primer	caagaaggatgctttATGAAGATTGCGGTTGCAGG	SP6

	SP1_R6_primer	ctcctcgcccttggaATCGACAATAGGACTTTTCC	
7	SP7_F2_primer	caagaaggatgctttATGTTTGCGTGCGTAGCC	SP7
	SP1_R7_primer	ctcctcgcccttggaGGTGGAGGTGGATTCGG	
8	SP8_F2_primer	caagaaggatgctttATGGTTGGTGACGACACC	SP8
	SP1_R8_primer	ctcctcgcccttggaCATCGTTGCCTCGCCCG	
9	SP9_F2_primer	caagaaggatgctttATGGGCACCATGATGCG	SP9
	SP1_R9_primer	ctcctcgcccttggaGACGATCTGATGCGCCAGC	
10	SP10_F2_primer	caagaaggatgctttATGATGACTGGTGCACAGG	SP10
	SP1_R10_primer	ctcctcgcccttggaTCGCTGCTTGAGTTTGCCG	
11	SP11_F2_primer	caagaaggatgctttATGAAGTTCACCGTTGC	SP11
	SP1_R11_primer	ctcctcgcccttggaCAGCGTGGGCTCCCAAGCC	
12	SP12_F2_primer	caagaaggatgctttATGGTGTCTTTCAATAAACTGACC	SP12
	SP1_R12_primer	ctcctcgcccttggaGGAACGGGTCCACAGGGTG	
13	SP13_F2_primer	caagaaggatgctttATGGTCGCCGTCCTCAGG	SP13
	SP1_R13_primer	ctcctcgcccttggaAGACTCGCTAGCACAGCAC	
14	SP14_F2_primer	caagaaggatgctttTTGCCGGGACCTATATGTCC	SP14
	SP1_R14_primer	ctcctcgcccttggaTTGGGCCACTATTGTCTTC	
15	SP15_F2_primer	caagaaggatgctttATGAAACGTAGCGATTATATGTTGG	SP15
	SP1_R15_primer	ctcctcgcccttggaCTTGCCTGAGGCATCTTG	
16	SP16_F2_primer	caagaaggatgctttATGAGCAATAGTGCATCATCG	SP16
	SP1_R16_primer	ctcctcgcccttggaGGCCAACGGAGTCGTCTCG	
19	SP19_F2_primer	caagaaggatgctttTTGGCAAGATGGGTCACTC	SP19
	SP19_R2_primer	ctcctcgcccttggaGCCCATGACCGGCATGAAC	
21	SP21_F2_primer	caagaaggatgctttATGGCATTGACTGATGAACAGG	SP21
	SP21_R2_primer	ctcctcgcccttggaACGTGCAGTGGTATGGATG	
22	SP22_F2_primer	caagaaggatgctttTTGGTGTCTATGAGAAGC	SP22
	SP22_R2_primer	ctcctcgcccttggaGATGCGCTCACGCTTGG	
23	SP23_F2A_primer	gaaggatgctttATGAACAAGCGATGGAAC	SP23
	SP23_R2_primer	ctcctcgcccttggaGATCGTCTTGAGAATCTTCAGAC	

24	SP24_F2_primer	caagaaggatgctttATGGTCGGCATGCGCGAC	SP24
	SP24_R2_primer	ctcctcgcccttggaGTTGGTGCGGTTCCGGTAG	
25	SP25_F2_primer	caagaaggatgctttGTGATGTTATCCACACC	SP25
	SP25_R2_primer	ctcctcgcccttggaCTGCTCATGATCGGCCCAG	

[0118]

PCR was performed in a similar way to Production Example 1 above, and the prepared PCR products were named as SPx (x=1-16, 19, 21-25).

[0119]

Vector Preparation

Vectors for cloning SPx were prepared as follows. A summary of the preparation is shown in Fig. 2. Plasmid pScHuGFPuv vector (Fig. 2, top panel, right figure; SEQ ID No.: 2) was fully digested with HindIII (Fermentas). Reacting conditions were in accordance to the instruction of the enzyme. Digested plasmid was fractioned by electrophoresis on 0.8% agarose gel for purification (1 x TBE buffer, with ethidium bromide), and a straight chain DNA fragment of approximately 4.6 kbps was cut out, and DNA was extracted from agarose and purified using DNA extraction kit from a gel (QIAquick Gel Extraction Kit, QIAGEN). Purified DNA fragment (vector) was electrophoresed on 0.8% agarose gel (1 x TBE buffer, with ethidium bromide) with a DNA concentration marker to estimate its concentration.

For GFPuv coding sequence in pScHuGFPuv vector, codons have been optimized (GenScript) for *Bifidobacterium*.

[0120]

Recombination Reaction

The vector and insert prepared above were mixed in 1: 3 to 10 molar ratio, and linked by recombination reaction (CloneEZ Kit, GenScript). Reaction conditions were in accordance with the product instruction.

[0121]

Transformation of *E. coli*

E. coli TOP10 chemically Competent Cell (Life Technologies Japan) was transformed using 2μL of the recombination reaction solution above, smeared onto a LB (containing 75μg/mL spectinomycin) plate and cultured overnight at 37°C. Transforming conditions were in accordance with the product instruction.

The transformed *E. coli* colonies were cultured overnight in a LB (containing 75μg/mL spectinomycin) liquid medium at 37°C, and plasmid was extracted from the culture (QIAprep Spin Miniprep Kit, QIAGEN). The insert sequence in this plasmid was determined, and the plasmid was named as pSPxB-GFP (x=1-16, 19, 21-25).

[0122]

Transformation of *Bifidobacterium*

Bifidobacterium was transformed in a similar way as Production Example 1 above.

[0123]

Production Example 3: Construction of a Secretory GFP-expressing Plasmid (pSec2-GFP)

A secretory peptide Sec2 has been reported in *Bifidobacterium breve* UCC2003 (Laura E. MacConaill et al., Applied and Environmental Microbiology, 2003 Vol. 69: pp6994-7001). From the genomic sequence of *B. longum* 105A, a sequence with high homology to Sec2 was searched and its secretory signal was linked to a coding sequence of GFP. A plasmid which expresses this by a HU promoter was constructed using the plasmid pScHuGFPuv vector of Production Example 2. A summary is shown in Fig. 3. Details are given below.

[0124]

Insert Preparation

Sec2-F1 primer and Sec2-R2 primer were designed at the translation start site of Sec2 gene and at 123bps downstream of the signal peptide coding sequence of *B. longum* 105A, respectively. Primer sequences are shown in Table 2.3. 15 nucleotides at 5' side of each primer have a homologous sequence to the vector shown below.

[0125]

Table 2.3 Primers for amplification of signal peptides (Sec2)

	Primer Name	Sequence (5' -> 3')	PCR product
Sec2	Sec2-F1 primer	caagaaggatgctttTTGGAACATATGAAGATGTTCC	Sec2
	Sec2-R2 primer	ctcctcgcccttggaGTCGAGTTTCATTGTATCG	

[0126]

PCR was performed in a similar way to Production Example 1 above, and the prepared PCR product was named as Sec2.

[0127]

Vector Preparation

Preparation was in a similar way as Production Example 2 above, using a plasmid pScHuGFPuv vector (Fig. 3, top panel, right figure; SEQ ID No.: 2)

[0128]

Recombination Reaction

The vector and insert prepared above were mixed in 1:10 molar ratio, linked by a recombination reaction (CloneEZ Kit, GenScript). Reacting conditions were in accordance with the product instruction.

[0129]

Transformation of *E. coli*

E. coli TOP10 chemically Competent Cell (Life Technologies Japan) was transformed using 2μL of the recombination reaction solution above. Transforming conditions were in accordance with the product instruction.

The transformed *E. coli* colonies were cultured overnight in a LB (containing 75μg/mL spectinomycin) liquid medium at 37°C, and plasmid was extracted from the culture (QIAprep Spin Miniprep Kit, QIAGEN). The insert sequence in this plasmid was determined, and the plasmid was named as pSec2-GFP (SEQ ID No.: 3).

[0130]

Transformation of *Bifidobacterium*

Bifidobacterium was transformed in a similar way as Production Example 1 above.

[0131]

Working Example 1: GFP Protein Expression of Recombinant Bifidobacteria

The recombinant bifidobacteria obtained from Production Examples 1 to 3 (*Bifidobacterium longum* 105A/pSPxA-GFP (x=1-16), *Bifidobacterium longum* 105A/pSPxB-GFP (x=1-16, 19, 21-25) and *Bifidobacterium longum* 105A/ pSec2-GFP) in glycerin stock solution were inoculated at 1% in APS-2S-2.5SE (75μg/mL spectinomycin) liquid medium and cultured in anaerobic condition at 37°C for 24 hours (activating culture solution).

[0132]

Subsequently, the activating culture solution was inoculated at 0.5% in a medium (for each 20mL of APS-2S-2.5SE (75μg/mL spectinomycin) liquid medium, 4mL of 1M sodium phosphate buffer (pH6.8) was added). This was cultured in anaerobic condition at 37°C for 18 hours.

This culture solution was used to prepare culture supernatant and intracellular proteins as follows.

[0133]

The culture solution was centrifuged and then culture supernatant was collected. Proteins in this culture supernatant were precipitated by trichloroacetic acid (TCA), washed with acetone, dissolved in an electrophoresis buffer, and the proteins in the culture supernatant were concentrated. Besides, intracellular proteins were extracted as follows. 1mL of the culture solution was mixed with 4mL of PBS, centrifuged at 12,000rpm for 5 minutes at 4°C, and the supernatant was removed. The precipitation was suspended in 5mL PBS and centrifuged to remove the supernatant, which was repeated twice. After washing, the cells were made to the total volume of 1mL with PBS, homogenized with a sonicator. After centrifugation, the supernatant was collected to provide an intracellular extract.

[0134]

A similar operation was performed for wild type *Bifidobacterium longum* 105A for a negative control. For a positive control for GFP protein, recombinant GFPuv (Clontech) was used.

The culture supernatant concentrate (corresponding to 1mL culture solution) and intracellular protein extract (corresponding to 7.5μL culture solution) above were electrophoresed on 12.5% tris-glycine gel (ATTO Corporation, e-PAGEL®). This was transferred to a PVDF membrane (Invitrogen, iBlot® Transfer Stacks) using iBlot® Transfer Device (Invitrogen). After blotting, the membrane was blocked, then reacted with a rabbit GFP antibody (Clontech, A.v. peptide Antibody Living Colors) as primary antibody and anti-Rabbit IgG HRP Conjugate (Santa Cruz Biotechnology) as secondary antibody, and developed with ECL Advance Western blotting Detection Kit (GE Healthcare). This was analyzed by an imaging analyzer (Fluor S Max, Bio-Rad).

[0135]

As a result, 13 bacteria (*B. longum* 105A/pSP1B-GFP, *B. longum* 105A/pSP2B-GFP, *B. longum* 105A/pSP3B-GFP, *B. longum* 105A/pSP4B-GFP, *B. longum* 105A/pSP7B-GFP, *B. longum* 105A/pSP9B-GFP, *B. longum* 105A/pSP10B-GFP, *B. longum* 105A/pSP12B-GFP, *B. longum* 105A/pSP16B-GFP, *B. longum* 105A/pSP23B-GFP, *B. longum* 105A/pSP7A-GFP, *B. longum* 105A/pSP12A-GFP and *B. longum* 105A/pSec2-GFP) showed secreting tendency. Similar test was performed twice, and prominent secretory effect was confirmed particular in 5 (*B. longum* 105A/pSP3B-GFP, *B. longum* 105A/pSP7B-GFP, *B. longum* 105A/ pSP23B-GFP, *B. longum* 105A/pSP7A-GFP and *B. longum* 105A/pSec2-GFP) (Fig. 4).

[0136]

Working Example 4: Production of a Secretory TNF alpha-expressing *Bifidobacterium* (pSPxA-TNF alpha and pSPxB-TNF alpha)

Construction of Plasmid Vector pTNF1

The codons of coding sequence of human TNFα (Accession No. X01394) were optimized for *Bifidobacterium* and inserted into pUC57vector (outsource synthesis to GenScript). This plasmid was used as template for PCR (PrimeSTAR® HS Premix, TAKARA BIO, Inc.) targeting to TNFα coding region using TNF-F1 primer and TNF-R1 primer (Table 3). PCR product was purified (QIAquick PCR purification Kit, QIAGEN) and electrophoresed on 0.8% agarose gel, and a DNA fragment of

approximately 0.7kbps was cut out. DNA was extracted from this gel (QIAquick Gel Extraction Kit, QIAGEN) to provide the insert.

[0137]

Table 3 Primers for constructing plasmid vector pTNF1

Primers	Sequence (5' -> 3')
TNF-F1 primer	gaaggatgctttATGTCCACCGAATCCATGATCCG
TNF R1 primer	acgagcagaaggTCACAGGGCGATGATGCCGAAG

[0138]

Besides, the vector was prepared as follows. 10μL each of the restriction enzymes FastDigest Bsp119 I, FastDigest Pst I, FastDigest Nde I and FastDigest Acl I (Fermentas) were added to 10μg of plasmid pCDshuttle (Patent literature 9; WO2009/128272A1) and incubated at 37°C for 4.5 hours to fully digest the plasmid. This was electrophoresed on0.8% agarose gel, and a DNA fragment of approximately 3.9 kbps was cut out. DNA was extracted from this gel (QIAquick Gel Extraction Kit, QIAGEN) to provide the vector.

[0139]

20 ng of the vector and 36ng of the insert above were linked by recombination of terminal sequences using CloneEZ Kit (GenScript). Details were in accordance with the product instruction of CloneEZ Kit. 2μL of this DNA was used for transforming *E. coli* TOP10 chemically Competent Cell (Life Technologies Japan). Transforming conditions were in accordance with the product instruction.

Transformed *E. coli* colonies were cultured overnight in LB (containing 75μg/mL spectinomycin) liquid medium at 37°C, and plasmid was extracted from this culture (QIAprep Spin Miniprep Kit, QIAGEN). This plasmid was named as pTNF1 (Fig. 5, top panel, right figure; SEQ ID No.: 4).

[0140]

The construction summaries of plasmids pSPxA-TNF alpha and pSPxB-TNF alpha in which the GFP portion of plasmids pSPxA-GFP and pSPxB-GFP has been replaced by TNF alpha were shown in Figs. 5 and 6, respectively.

Plasmid pTNF1 was used as template for PCR (PrimeSTAR® HS Premix, TAKARA BIO, Inc.) using TNFvec F1 primer and TNFvec R1 primer (Table 4), and PCR product of approximately 3.8 kbps was obtained to provide the vector.

[0141]

Table 4 Vector primers for constructing pSPxA-TNF alpha and pSPxB-TNF alpha

Primers	Sequence (5' -> 3')
TNFvec_F1_primer	GTGCGCTCCTCCTCCCGTAC
TNFvec_R1_primer	GCCGTAGTTAGGCCACCACTTCAAG

[0142]

Besides, the plasmid pSPxA-GFP (x=7 or 12) or pSPxB-GFP (x=1-4, 7, 9, 10, 12, 16 or 23) which showed secreting tendency in Working Example 1 was used as template for PCR amplification (PrimeSTAR® HS Premix, TAKARA BIO, Inc.) of the insert using primers of Table 5, to provide the insert.

[0143]

Table 5 Insert primers for constructing pSPxA-TNF alpha, pSPxB-TNF alpha and pSec2-TNF alpha

PCR product for	Primers	Sequence (5' -> 3')	Template Plasmid
pSP7A-TNF	pUC_ori_F2 primer	tggcctaactacggctacac	pSP7A-GFP
	SP7-TNF_R1 primer	ggaggaggagcgcacGGTGGAGGTGGATTCGGCGAAC	
pSP12A-TNF	pUC_ori_F2 primer	tggcctaactacggctacac	pSP12A-GFP

	SP12-TNF_R1 primer	ggaggaggagcgcacGGAACGGGTCCACAGGGTGAT	
pSP1B-TNF	pUC_ori_F2 primer	tggcctaactacggctacac	pSP1B-GFP
	SP1B-TNF_R1 primer	ggaggaggagcgcacTTCCACGCGCTCCTTGGCGATG	
pSP2B-TNF	pUC_ori_F2 primer	tggcctaactacggctacac	pSP2B-GFP
	SP2B-TNF_R1 primer	ggaggaggagcgcacCAAAAACAGCACGCGGGTG	
pSP3B-TNF	pUC_ori_F2 primer	tggcctaactacggctacac	pSP3B-GFP
	SP3B-TNF_R1 primer	ggaggaggagcgcacGGCGATGGTCAGCTTGC	
pSP4B-TNF	pUC_ori_F2 primer	tggcctaactacggctacac	pSP4B-GFP
	SP4B-TNF_R1 primer	ggaggaggagcgcacGCCGAACAGACGCGGGGGAA	
pSP7B-TNF	pUC_ori_F2 primer	tggcctaactacggctacac	pSP7B-GFP
	SP7-TNF_R1 primer	ggaggaggagcgcacGGTGGAGGTGGATTCGGCGAAC	
pSP9B-TNF	pUC_ori_F2 primer	tggcctaactacggctacac	pSP9B-GFP
	SP9B-TNF_R1 primer	ggaggaggagcgcacGACGATCTGATGCGCCAGCGCATC	
pSP10B-TNF	pUC_ori_F2 primer	tggcctaactacggctacac	pSP10B-GFP
	SP10B-TNF_R1 primer	ggaggaggagcgcacTCGCTGCTTGAGTTTGCCGGAAATC	
pSP12B-TNF	pUC_ori_F2 primer	tggcctaactacggctacac	pSP12B-GFP
	SP12-TNF_R1 primer	ggaggaggagcgcacGGAACGGGTCCACAGGGTGAT	
pSP16B-TNF	pUC_ori_F2 primer	tggcctaactacggctacac	pSP16B-GFP
	SP16B-TNF_R1 primer	ggaggaggagcgcacGGCCAACGGAGTCGTCTC	
pSP23B-TNF	pUC_ori_F2 primer	tggcctaactacggctacac	pSP23B-GFP
	SP23B-TNF_R1 primer	ggaggaggagcgcacGATCGTCTTGAGAATCTTCAGACG	

pSec2-TNF	Sec2_out1_primer	tacGGATCCgtcttcctgctg	pSec2-GFP
	Sec2a_R1_primer	GTACGGGAGGAGGAGCGCACGTCGAGTTTCATTGTATCG	
pSec2-TNF	Sec2a_F1_primer	CGATACAATGAAACTCGACGTGCGCTCCTCCTCCCGTAC	pTNF1
	TNF_out1_primer	aggACTAGTccggaataatacgg	

[0144]

100ng of the vector and 40ng of the insert above were linked by In-Fusion™ Advantage PCR Cloning Kit (TAKARA BIO, Inc.). 2μL of this DNA was used for transforming *E. coli* TOP10 chemically Competent Cell (Life Technologies Japan). Transforming conditions were in accordance with the product instruction.

[0145]

Transformed *E. coli* colonies were cultured overnight in LB (containing 75μg/mL spectinomycin) liquid medium at 37°C, and plasmids were extracted from this culture (QIAprep Spin Miniprep Kit, QIAGEN). These plasmids were fully sequenced and their plasmid names were assigned as pSP7A-TNF alpha, pSP12A-TNF alpha, pSP1B-TNF alpha, pSP2B-TNF alpha, pSP3B-TNF alpha, pSP4B-TNF alpha, pSP7B-TNF alpha, pSP9B-TNF alpha, pSP10B-TNF alpha, pSP12B-TNF alpha, pSP16B-TNF alpha, pSP23B-TNF alpha.

[0146]

Transformation of Bifidobacteria with pSPxA-TNF alpha and pSPxB-TNF alpha

Plasmids pSPxA-TNF alpha and pSPxB-TNF alpha were used for transforming *B. longum* 105A in a similar way as Production Example 1.

[0147]

Reference Example 2: Construction of Plasmid pTNF3

We constructed a shuttle vector (*Bifidobacterium* - *E. coli*) in which the mature human TNFα coding sequence is located downstream of Hu promoter derived from *Bifidobacterium*. A summary is shown in Fig. 12. Details are as follows.

[0148]

Insert Preparation

We constructed a plasmid human TNFalpha_in_pUC57 containing an artificial DNA having human TNFα (Accession No:X01394; from 153th to 854th nucleotides of an immature TNFα coding sequence) of which codons are optimized for *Bifidobacterium*, and Hu promoter derived from *Bifidobacterium* located upstream thereof and Hu terminator derived from *Bifidobacterium* located downstream thereof (custom-synthesized by GenScript).

1ng of the plasmid human TNFalpha_in_pUC57 was used as template for PCR amplification of the mature TNFα portion of the TNFα coding sequence by PrimeSTAR® HS Premix (TAKARA BIO, Inc.). TNF F3 and TNF R1 primers were used, wherein the 15 nucleotides of the 5' side of each primer had a homologous sequence to the vector terminal (Table 6). The PCR program consisted of 30 cycles of 10 seconds at 98°C, 5 seconds at 60°C and 30 seconds at 72°C, followed by 30 seconds at 72°C.

A part of PCR product was electrophoresed with DNA concentration marker on 2% agarose gel (1 x TBE buffer, containing ethidium bromide), confirming a single band of approximately 0.5kbp and estimating its concentration.

[0149]

Vector Preparation

1ng of the plasmid pCDshuttle was used as template for PCR amplification of the vector skeletal by PrimeSTAR® HS Premix (TAKARA BIO, Inc.). Primers pCDshuttle F1 and pCDshuttle R1 were used, wherein the 15 nucleotides on the 5' side of each primer had a homologous sequence to the insert terminal (Table 6). The PCR program consisted of 30 cycles of 10 seconds at 98°C, 5 seconds at 55°C and 4 minutes at 72°C, followed by 30 seconds at 72°C.

A part of PCR product was electrophoresed with DNA concentration marker on 0.8% agarose gel (1 x TBE buffer, containing ethidium bromide), confirming a single band of approximately 3.9kbps.

[0150]

Table 6: Primers for pTNF3 construction

[0151]

Cloning

100ng of the vector and 50ng of the insert above were ligated by recombination of terminal sequences using In-Fusion Advantage PCR Cloning Kit (TAKARA BIO, Inc.). At this time, Cloning Enhancer (TAKARA BIO, Inc.) was also added into the reacting solution, concurrently degrading the template plasmid contained in the vector and the insert. Details were in accordance with the product instruction of In-Fusion Advantage PCR Cloning Kit.

2μL of the In-Fusion reaction solution above was used for transforming *E. coli* TOP10 chemically Competent Cell (Invitrogen). Transforming conditions were in accordance with the product instruction. Transformed *E. coli* colonies were cultured overnight at 37°C in LB (containing 75μg/mL spectinomycin) liquid medium, and the plasmid was extracted from this culture (QIAprep Spin Miniprep Kit, QIAGEN). This plasmid was full-sequenced and named pTNF3 (SEQ ID No: 51).

[0152]

Transformation of *Bifidobacterium*

The plasmid pTNF3 was used for transforming *B. longum* 105A using a similar method as Production Example 1.

[0153]

Production Example 5: Production of a Secretory TNF alpha-expressing *Bifidobacterium* (pSec2-TNF alpha)

Summary of the construction of pSec2-TNF alpha, a plasmid in which the GFP portion of the plasmid pSec2-GFP was replace by TNF alpha, is shown in Fig. 7.

[0154]

Vector Preparation

Plasmid pCDshuttle was fully digested with BamHI, BcuI and PstI (all from Fermentas). Reacting conditions were in accordance with the instruction of the enzymes. Digested plasmid was fractioned by electrophoresis on 1% agarose gel for purification (1 x TBE buffer, with ethidium bromide), and a large fragment of approximately 3.4kbps was cut out, and DNA was extracted from the agarose gel by DNA extraction kit (QIAquick Gel Extraction Kit, QIAGEN). Purified DNA fragment

(vector) was electrophoresed on 0.8% agarose gel (1 x TBE buffer, with ethidium bromide) with DNA concentration marker to estimate its concentration.

[0155]

Insert Preparation

Plasmid pSec2-GFP was used as template for PCR amplification of Sec2 signal peptide coding sequence including HU promoter with Sec2_out1 primer and Sec2a_R1 primer (Table 5) (PCR product 1). Besides, plasmid pTNF1 was used for PCR amplification of TNF alpha coding sequence including HU terminator with Sec2a_F1 primer and TNF_out1 primer (Table 5) (PCR product 2). PCR products 1 and 2 were purified with PCR product purification kit (QIAquick PCR purification kit, QIAGEN), and the amount of PCR products was estimated by absorption measurement. PCR product 1 and PCR product 2 were mixed in equimolar amount. This PCR product mixture solution 1ng plus 2 x PCR Solution PrimeSTAR HS (TAKARA BIO, Inc.) was made to 49μL with 0.1 x TE buffer. This solution was set in a thermal cycler, and two PCR fragments were linked by the reaction of 5 cycles, each cycle consisting of 98°C for 10 seconds and 72°C for 36 seconds. Then, the linked PCR product was amplified by adding Sec2_out1 primer and TNF_out1 primer, reacting 25 cycles, each cycle consisting of 98°C for 10 seconds, 55°C for 5 seconds and 72°C for 70 seconds, before elongation at 72°C for 30 seconds.

[0156]

This was fractioned by electrophoresis on 1% agarose gel for purification (1 x TBE buffer, with ethidium bromide), and a fragment of approximately 1.2kbp was cut out, and DNA was extracted and purified from the agarose gel using DNA extraction kit (QIAquick Gel Extraction Kit, QIAGEN). This purified DNA fragment was fully digested with BamHI and BcuI. Reacting conditions were in accordance with the instruction of the enzymes. Digested plasmid was fractioned by electrophoresis on 1% agarose gel for purification (1 x TBE buffer, with ethidium bromide), and a DNA fragment of approximately 1.2kbp was cut out, and DNA was extracted and purified from agarose gel using DNA extraction kit (QIAquick Gel Extraction Kit, QIAGEN). Purified DNA fragment (insert) was electrophoresed on 0.8% agarose gel (1 x TBE

buffer, with ethidium bromide) with DNA concentration marker to estimate its concentration.

[0157]

Ligation

The vector and the insert above were mixed in 1:3 molar ratio for ligation (Rapid DNA Ligation Kit, Fermentas). Details were in accordance with the product instruction.

[0158]

Transformation of *E. coli*

2μL of the ligation reaction solution above was used for transforming *E. coli* TOP10 chemically Competent Cell (Life Technologies Japan). Transforming conditions were in accordance with the product instruction.

Transformed *E. coli* colonies were cultured overnight in LB (containing 75μg/mL spectinomycin) liquid medium at 37°C, and plasmids were extracted from this culture (QIAprep Spin Miniprep Kit, QIAGEN). The insert part of this plasmid was fully sequenced to confirm that there was no PCR error, and the plasmid was named as pSec2-TNF alpha.

[0159]

Transformation of *Bifidobacterium* with pSec2-TNF alpha

Plasmid pSec2-TNF alpha was used for transforming *B. longum* 105A in a similar way as Production Example 1.

[0160]

Working Example 2: TNF alpha Protein Expression by Recombinant *Bifidobacterium*

The recombinant bifidobacteria obtained from Production Example 4 and Production Example 5 (*Bifidobacterium longum* 105A/ pSPxA-TNF alpha (x=7, 12)、*Bifidobacterium longum* 105A/pSPxB-TNF alpha(x=1-4, 7, 9, 10, 12, 16 or 23) and *Bifidobacterium longum* 105A/pSec2-TNF alpha) in glycerin stock solution were inoculated at 1% in APS-2S-2.5SE (75μg/mL spectinomycin) liquid medium and cultured in anaerobic condition at 37°C for 24 hours (activation culture solution).

[0161]

Subsequently, the activating culture solution was inoculated at 0.5% in a medium (for each 20mL of APS-2S-2.5SE (75μg/mL spectinomycin) liquid medium, 4mL of 1M sodium phosphate buffer (pH6.8) was added). This was cultured in anaerobic condition at 37°C for 18 hours.

After centrifuging the culture solution, culture supernatant was collected. Proteins in this culture supernatant was precipitated by trichloroacetic acid (TCA), washed with acetone, dissolved in a buffer for electrophoresis, and proteins in the culture supernatant were concentrated.

[0162]

Besides, intracellular proteins were extracted as follows. 1mL of the culture solution was mixed with 4mL of PBS, centrifuged at 12,000rpm for 5 minutes at 4°C, and the supernatant was removed. The precipitation was suspended in 5mL PBS and centrifuged to remove the supernatant, which was repeated twice. After washing, the cells were made to the total volume of 1mL with PBS, homogenized with a sonicator. After centrifugation, the supernatant was collected to provide an intracellular extract, which was then subjected to westernblot analysis.

[0163]

A similar operation was performed for wild type *Bifidobacterium longum* 105A for a negative control. For a positive control for TNF alpha, human recombinant TNF alpha (PEPRO TECH, INC.) was used.

[0164]

The culture supernatant (corresponding to 7.5μL culture solution), culture supernatant concentrate (corresponding to 1mL culture solution) and intracellular protein extract (corresponding to 7.5μL culture solution) above were electrophoresed on 16% Tris-Glycine gel (Invitrogen). Note that, for following samples, the amount applied was adjusted as follows. The supernatant of SP3B-TNF alpha corresponding to 0.15μL culture solution, the intracellular protein extract of SP16B-TNF alpha corresponding to 0.15μL, the intracellular protein extract of SP23B-TNF alpha corresponding to 0.75μL, the culture supernatant concentrate of the same corresponding to 20μL and 100μL were subjected for electrophoresis. These were transferred to PVDF membranes (Invitrogen, iBlot® Transfer Stacks) using iBlot®

Transfer Device (Invitrogen). After blotting, the membranes were blocked, then reacted with anti-human TNF-alpha (goat) (R&D Systems) as primary antibody and anti-Goat IgG HRP Conjugate (Santa Cruz Biotechnology) as secondary antibody, and developed with ECL Advance Western blotting Detection Kit (GE Healthcare). These were analyzed by an imaging analyzer (Fluor S Max, Bio-Rad). The results of the analyses are shown in Fig. 8.

[0165]

As a result, secretion was confirmed in 9 bacteria (*B. longum* 105A/pSP1B- TNF alpha, *B. longum* 105A/pSP3B- TNF alpha, *B. longum* 105A/pSP4B- TNF alpha, *B. longum* 105A/pSP7B- TNF alpha, *B. longum* 105A/pSP12B- TNF alpha, *B. longum* 105A/pSP16B- TNF alpha, *B. longum* 105A/pSP23B- TNF alpha, *B. longum* 105A/pSP7A- TNF alpha and *B. longum* 105A/pSec2-TNF alpha), with particularly prominent expression in the culture supernatant of 2 bacteria (*B. longum* 105A/SP3B-TNF alpha and *B. longum* 105A/SP23B-TNF alpha).

[0166]

Reference Example 3: Confirmation of Secretion by a non-TNFα-secretory bacterium *B. longum* 105A/pTNF 3

The glycerin stocks of *B. longum* 105A/pTNF3 obtained in Reference Example 2 and wild-type *B. longum* 105A were inoculated at 1% to APS-2S-2.5SE (75μg/mL spectinomycin) liquid medium, cultured in anaerobic condition at 37°C for 24 hours (activating culture solution). The activating culture solution was inoculated at 0.5% to a medium (75μg/mL spectinomycin) (for each 20mL of APS-2S-2.5SE liquid medium added 4mL of 1M sodium phosphate buffer (pH6.8)), which was cultured in anaerobic condition at 37°C for 18 hours. Note that wild-type was cultured in a medium which was not supplemented with spectinomycin. This culture solution was centrifuged to collect a culture supernatant. Meanwhile, an intracellular extract was prepared as follows. 1mL of the culture solution was washed with PBS buffer, then the cells were suspended in PBS buffer to make 1mL and homogenized with a sonicator. This was centrifuged, and the supernatant was collected to give an intracellular extract.

[0167]

A sample obtained from wild-type was used as a negative control. As a

positive control, human-derived recombinant TNF alpha (PEPRO TECH, INC.) was used. The culture supernatant (corresponding to 7.5μL of the culture solution) and intracellular extract (corresponding to 0.075μL of the culture solution) above were electrophoresed on 15% polyacrylamide gel (ATTO Corporation). This was transferred to a PVDF membrane (Invitrogen, iBlotTransfer Stacks) using iBlot Transfer Device (Invitrogen). After blotting, the membrane was blocked and reacted using anti-human TNF-alpha(goat) (R&D Systems) as a primary antibody and anti-Goat IgG HRP Conjugate (Santa Cruz Biotechnology) as a secondary antibody, and developed by ECL Advance Western blotting Detection Kit (GE Healthcare). It was analyzed with an imaging analyzer (Fluor S Max, Bio-Rad). The results of the analyses are shown in Fig. 9.

[0168]

As a result, when the intracellular extracts of *B. longum* 105A/pTNF3 and wild-type *B. longum* 105A were compared, a band indicating TNFα expression was confirmed in *B. longum* 105A/pTNF3 but not in wild-type *B. longum* 105A. Thus, it was shown that the cells transformed with the plasmid pTNF3 normally express TNFα. However, comparing both culture supernatants confirmed no TNFα in either culture supernatant, indicating that TNFα is not extracellulary secreted from *B. longum* 105A/pTNF3.

[0169]

Production Example 6: Construction of pBifi-SP3B-TNF

Plasmid pBifi-SP3B-TNF was constructed from plasmid pSP3B-TNF alpha (*E. coli* - *Bifidobacterium* shuttle vector) by removing the origin of replication in *E. coli*. Details of the construction are shown in Fig. 10.

[0170]

Preparation of pUCori-removed Fragment

2.4μg of plasmid extracted from the recombinant *E. coli.* TOP10/pSP3B-TNF alpha (shuttle vector) was digested by BamHI and BglII at 37°C. This was fractioned by electrophoresis using 0.8% agarose gel for purification, and a DNA fragment of approximately 3.8kbps was cut out. DNA was extracted and purified from the cut-out

gel (QIAquick Gel Extraction Kit, QIAGEN), and DNA concentration was measured by measuring the absorbance.

[0171]

Self-ligation of pUCori-removed fragment

The pUCori-removed fragment above was self-ligated in 6 tubes. For each tube, 50ng of pUCori-removed fragment was used for self-ligation in 50μL reaction system at 25°C for 5 minutes (RAPID DNA LIGATION KIT, Fermentas), then Ligase was deactivated by heating at 65°C for 5 minutes. 6 ligation reaction solutions were assembled to one tube, and subjected to protein degradation by Proteinase K and subsequent protein removal by phenol/chloroform extraction and ethanol precipitation thereafter. DNA was dissolved in 10μL 0.1 x TE.

[0172]

Transformation of *Bifidobacterium*

Bifidobacterium longum 105A competent cell was transformed (electroporation, Gene Pulser II, Bio-Rad Laboratories, Inc.) using 150ng (5μL) of the purified product after the ligation above. Immediately after an electric shock, a mixture of 800μL of IMR liquid medium and 50μL of vitamin C additive solution was added to the cuvette, which was then collected in a sterilized 2mL microtube. The lid of tube was loosen, and the tube was placed in a dessicator, which was then deaerated by a vacuum pump and filled with carbon dioxide This manipulation was repeated three times to replace the air in the dessicator with carbon dioxide, before placing the dessicator in an incubator set to 37°C and incubating for 3 hours.

[0173]

After the incubation, the bacterial suspension was mixed thoroughly and smeared to two IMR agar media (containing 75μg/mL SPCM). These plates were placed in a sealed vessel with deoxygenating/carbon dioxide-generating agent (Anaero Pac®-Anaero, MITSUBISHI GAS CHEMICAL, INC.) and cultured for two days in an incubator set to 37°C.

[0174]

Confirmation of the Transformant and Production of a Glycerin Stock of Recombinant *Bifidobacterium*

The colonies of candidate recombinant formed on the IMR agar media (containing 75μg/mL SPCM) above were streaked on BL-bS agar media (BL agar media containing spectinomycin, excluding horse defibrinated blood), placed in a sealed vessel with deoxygenating/carbon dioxide-generating agent (Anaero Pac®-Anaero, MITSUBISHI GAS CHEMICAL, INC.) and cultured for one day at 37°C. The streak-cultured bifidobacteria was cultured in anaerobic condition in APS-2S-2.5SE (75μg/mL spectinomycin) liquid medium at 37°C for one day, and plasmid DNA was extracted from this (QIAprep Spin Miniprep Kit, QIAGEN). The extracted DNA was used as template for PCR amplification with Check primer F1 (on AAD9 cassette) and Check primer R2 (on HU promoter), and PCR product size was confirmed by agarose-gel electrophoresis. Primer sequences are shown in Table 6. Locations of PCR primers are shown in Fig. 9. PCR product size was approximately 0.5kbps, confirming the exclusion of pUC ori fragment. This result confirmed that this recombinant *Bifidobacterium* possesses pBifi-SP3B-TNF alpha, a plasmid in which pUC ori has been removed from pSP3B-TNF alpha.

[0175]

Table 7 Primers for confirmation of shuttle and non-shuttle vectors

Primers	Sequence (5' -> 3')
Check primer F1	TGACTTAGAGGAATTACTACCTG
Check primer R2	AAAGTGGCGGAAAGCGCCAC

[0176]

The streak culture on BL-bS agar medium was inoculated in APS-2S-2.5SE (75μg/mL spectinomycin) liquid medium and cultured at 37°C for 24 hours. To this culture solution glycerin solution was added to make a final concentration of 20%, to give a glycerin stock.

[0177]

Nucleotide Sequencing of Plasmid pBifi-SP3B-TNF

The glycerin stock of *Bifidobacterium longum* 105A/pBifi-SP3B-TNF was cultured in anaerobic condition in APS-2S-2.5SE (75μg/mL spectinomycin) liquid medium. Bacterial cells were collected from the culture solution by centrifugation, suspended in 30mM GTA buffer, then treated with *N*-acetyl muramidase. It was further treated with Proteinase K (QIAGEN) before purification by plasmid DNA purification kit (QIAprep Spin Miniprep Kit, QIAGEN). This plasmid DNA was used for determination of full nucleotide sequence, confirming the exclusion of pUCori (SEQ ID No.: 5).

[0178]

Working Example 3: Confirmation of TNF alpha protein secretion from recombinant *Bifidobacterium*

The glycerin stock of *Bifidobacterium longum* 105A/pBifi-SP3B-TNF alpha obtained in Production Example 6 was inoculated at 1% in APS-2S-2.5SE (75μg/mL spectinomycin) liquid medium and cultured in anaerobic condition at 37°C for 24 hours (activating culture solution). The activating culture solution was inoculated at 0.5% in a medium (for each 20mL of APS-2S-2.5SE(75μg/mL spectinomycin) liquid medium, 4mL of 1M sodium phosphate buffer (pH6.8) was added), which was cultured in anaerobic condition at 37°C for18 hours. This culture solution was centrifuged and the culture supernatant was collected. Besides, the intracellular extract was prepared as follows. 1mL of the culture solution was washed with PBS, suspended in PBS to make 1mL, then homogenized by a sonicator. This was centrifuged and the supernatant was collected to give the intracellular extract. Similar manipulation was performed for a shuttle vector *Bifidobacterium longum* 105A/ pSP3B-TNF alpha and wild type *Bifidobacterium longum* 105A (wild type). Note that the wild type was cultured in a medium excluding spectinomycin. A sample obtained from the wild type was used as a negative control. For a positive control, human-derived recombinant TNF alpha (PEPRO TECH, INC.) was used.

[0179]

The culture supernatant (corresponding to 0.75μL culture solution) and intracellular protein extract (corresponding to 1.5μL culture solution) above were electrophoresed on 15% polyacrylamide gel (ATTO Corporation). This was transferred

to a PVDF membrane (Invitrogen, iBlot® Transfer Stacks) using iBlot® Transfer Device (Invitrogen). After blotting, the membrane was blocked, then reacted with anti-human TNF-alpha (goat) (R&D Systems) as primary antibody and anti-Goat IgG HRP Conjugate (Santa Cruz Biotechnology) as secondary antibody, and developed with ECL Advance Western blotting Detection Kit (GE Healthcare). This was analyzed by an imaging analyzer (Fluor S Max, Bio-Rad). The result of the analysis is shown in Fig. 11.

[0180]

Working Example 4: Transformation of *E. coli* with pBifi-SP3B-TNF alpha and pSP3B-TNF

Plasmids obtained from Production Example 6 (pBifi-SP3B-TNF alpha and pSP3B-TNF alpha) were used for transforming *E. coli.* TOP10 strain.

Transformation was performed in accordance with the product instruction of *E. coli.* TOP10competent cell (Life Technologies Japan), and 100μL each was smeared onto a LB (containing 75μg/mL spectinomycin) agar medium in duplicate, cultured overnight at 37°C. Colonies were formed only when the shuttle vector pSP3B-TNF alpha was introduced (266cfu and 226cfu), while *E. coli* in which pBifi-SP3B-TNF alpha was transferred formed no colony on the selection medium.

[0181]

Reference Example 4: Construction of Plasmid pBEshuttle

We constructed pBEshuttle as a mock vector having a protein expression unit containing no insert, as follows. A summary is shown in Fig. 13.

[0182]

PCR fragment Preparation

5ng of the plasmid pCDshuttle was used as template for amplifying two PCR fragments A and B using PrimeSTAR® HS Premix (TAKARA BIO, Inc.). MCS F1 primer and TNFvec R1 primer were used for the amplification of PCR fragment A, and pUC ori F2 primer and MCS R1 primer was used for the amplification of PCR fragment B (Table 8).

The 15 nucleotides on 5' side of the primer for the amplification of PCR fragment A was designed to have a homologous sequence to the terminal of PCR

fragment B, while the 15 nucleotides on 5' side of the primer for the amplification of PCR fragment B was designed to have a homologous sequence to the terminal of PCR fragment A.

The PCR program consisted of 30 cycles of 10 seconds at 98°C, 5 seconds at 55°C and X seconds (PCR fragment A: X=3 minutes 20 seconds, PCR fragment B: X=35 seconds) at 72°C, followed by 30 seconds at 72°C.

A part of PCR product was electrophoresed on an agarose gel (1 x TBE buffer, containing ethidium bromide; 0.8% agarose gel for PCR product A, 2% agarose gel for PCR product B) with DNA concentration marker, confirming a single band (PCR product A: approximately 3.3kbps, PCR product B: approximately 0.6kbps) and estimating its concentration.

[0183]

Table 8 Primers for pBEshuttle Construction

Primers	Sequence (5' -> 3')	PCR product
MCS_F1 primer	AAGCTTATCCTGCAGTGACCTTCTGCTCGTAGCGA	A
TNFvec_R1_primer	GCCGTAGTTAGGCCACCACTTCAAG	A
pUC_ori_F2_primer	TGGCCTAACTACGGCTACAC	B
MCS_R1 primer	CTGCAGGATAAGCTTCATAAAGCATCCTTCTTG	B

[0184]

Cloning

100ng of the PCR product A and 35ng of the PCR product B above were ligated by recombination of terminal sequences using In-Fusion Advantage PCR Cloning Kit (TAKARA BIO, Inc.). At this time, Cloning Enhancer (TAKARA BIO, Inc.) was also added into the reacting solution, concurrently degrading the template plasmid contained in the vector and the insert. Details were in accordance with the product instruction of In-Fusion Advantage PCR Cloning Kit.

2μL of the In-Fusion reaction solution above was used for transforming *E. coli* TOP10 chemically Competent Cell (Invitrogen). Transforming conditions were in

accordance with the product instruction. Transformed *E. coli* colonies were cultured overnight at 37°C in LB (containing 75μg/mL spectinomycin) liquid medium, and the plasmid was extracted from this culture (QIAprep Spin Miniprep Kit, QIAGEN). This plasmid was full-sequenced and named pBEshuttle (SEQ ID No: 50).

[0185]

Transformation of *Bifidobacterium*

The plasmid pBEshuttle was used for transforming *B. longum* 105A using a method as used in Production Example 1.

[0186]

Production Example 7: Production of Recombinant *Bifidobacterium B. breve*/pSP3B-TNF alpha

Bifidobacterium breve JCM1192 was transformed with the plasmid pSP3B-TNF alpha in a method as used in the transformation of *Bifidobacterium* in Production Example 1.

[0187]

Working Example 5: Confirmation of TNFα protein expression by Recombinant *Bifidobacterium*

The glycerin stocks of *B. longum* 105A/pBEshuttle obtained in Reference Example 4, *B. longum* 105A/pSP3B-TNF alpha obtained in Production Example 4, *B. longum* 105A/pBifiSP3B-TNF alpha obtained in Production Example 6 and *B. breve*/pSP3B-TNF alpha obtained in Production Example 7 were inoculated at 1% to APS-2S-2.5SE (75μg/mL spectinomycin) liquid media, cultured at 37°C for 24 hours in anaerobic condition (activating culture). The activating culture solution was inoculated at 0.5% to a medium (75μg/mL spectinomycin) (for each 20mL of APS-2S-2.5SE liquid medium added 4mL of 1M sodium phosphate buffer (pH6.8)), which was cultured at 37°C for 18 hours in anaerobic condition. This culture solution was centrifuged to collect a culture supernatant. TNFα content in the culture supernatant was measured by ELISA of the culture supernatant (Quantikine Human TNF alpha/TNFSF1A Immunoassay, R&D Systems, Inc.). The measurement results are shown in Table 9.

[0188]

Table 9

sample name	culture time (hrs)	OD(600nm)	TNFalpha conc. (μg/mL)
B. longum 105A /pBEshuttle	18	2.539	0
B. longum 105A/pSP3B-TNF alpha	18	1.806	0.69
B. longum 105A /pBifiSP3B-TNF alpha	18	1.509	0.42
B. breve /pSP3B-TNF alpha	12	6.864	1.94

[0189]

TNFα secretion was observed in the culture supernatant in either of *B. longum* 105A/pSP3B-TNF alpha, *B. longum* 105A/pBifiSP3B-TNF alpha and *B. breve*/pSP3B-TNF alpha, but not in *B. longum* 105A/pBEshuttle.

[0190]

Working Example 6: The Physiological Activity of TNFα Protein Secreted by Recombinant *Bifidobacteirum* and the Neutralization of the Physiological Activity with Anti-hTNFα Antibody

Culture of Test Bacterium and Preparation of Culture Supernatant

The glycerin stocks of *B. longum* 105A/pBEshuttle obtained in Reference Example 4, *B. longum* 105A/pSP3B-TNF alpha obtained in Production Example 4 and *B. longum* 105A/pBifiSP3B-TNF alpha obtained in Production Example 6 were inoculated at 1% to APS-2S-2.5SE (75μg/mL spectinomycin) liquid media, cultured at 37°C for 24 hours in anaerobic condition (activating culture). The activating culture solution was inoculated at 0.5% to a medium (75μg/mL spectinomycin) (for each 20mL of APS-2S-2.5SE liquid medium added 4mL of 1M sodium phosphate buffer (pH6.8)), which was cultured at 37°C for 18 hours in anaerobic condition. This culture solution was centrifuged to collect a culture supernatant.

[0191]

TNFα Cytotoxicity Assay

The physiological activity and neutralization of rhTNFα was assessed by examining the cytotoxicity via TNFα receptor, which is a physiological activity of TNFα. As a test cell, a human breast cancer cell line KPL-1 cell was used. KPL-1 cell was cultured in a DMEM medium (a DMEM medium supplemented with 10% (v/v) FBS and

0.1% (v/v) penicillin (50000U/mL)/streptomycin (50mg/mL) solution) at 37°C, in 5% CO_2 condition. This cell was seeded onto 96 well plate at 1 x 10^4 cells per well, cultured at 37°C in 5% CO_2 for 24 hours to give confluent cells. The old medium was removed from these cells by aspiration, and freshly added thereto were 80μL each per well of 10% (v/v) FBS supplemented with actinomycin D to make an actinomycin D final concentration of 5μg/mL and DMEM medium supplemented with 0.1% penicillin (50000U/mL)/streptomycin (50mg/mL) solution. Subsequently added were, as samples for measurement, a medium for *Bifidobacterium* (APS-2S-2.5SE), rhTNF alpha prepared at 100ng/mL as rhTNFα standard, five times dilution of *B. longum* 105A/pBEshuttle culture supernatant, five times dilution of *B. longum* 105A/pSP3B-TNF alpha culture supernatant and five times dilution of *B. longum* 105A/pBifiSP3B-TNF alpha culture supernatant, 10μL each per well. Added thereto in order to measure the neutralizing ability against rhTNFα physiological activity were anti-hTNFα antibody (anti-human TNF alpha, R&D Systems, 0.0125 - 0.1mg/mL), normal goat IgG (normal Goat IgG, R&D Sytems, 0.0125 - 0.1mg/mL), and 10% (v/v) FBS and DMEM medium supplemented with 0.1%(v/v) penicillin (50000U/mL)/ streptomycin (50mg/mL) solution, 10μL each per well. This plate was cultured at 37°C in 5% CO_2 for 48 hours.

[0192]

Measuring cytotoxicity employed Cell Counting Kit-8 (DOJINDO), wherein 10μL per well of this solution was added to each well, before further culturing for 4 hours at 37°C in 5% CO_2 and measuring of the absorbance at wavelength of 450nm and 630nm (630nm was used as reference wavelength). The results of the analyses are shown in Fig. 14, in which the culture supernatant of the recombinant bacteria *B. longum* 105A/pSP3B-TNF alpha and *B. longum* 105A/pBifiSP3B-TNF alpha showed cytotoxicity against KPL-1 cells while being neutralized by anti-TNFα antibody, confirming that the recombinant hTNFα secreted in the culture supernatant had a physiological activity.

[0193]

Working Example 7: Measurement of Antitumor Effect of *B. longum* 105A/pSP3B-TNF alpha and *B. breve*/pSP3B-TNF alpha

The antitumor effect of *B. longum* 105A/pSP3B-TNF alpha prepared in Production Example 4 and B.breve/pSP3B-TNF alpha prepared in Production Example 7 were measured.

[0194]

(1) Culturing of transplant tumor cells

Human breast cancer cell line KPL-1 cells were cultured in a DMEM medium supplemented with 10% (v/v) FBS and 0.1%(v/v) penicillin (50000U/mL)/streptomycin (50mg/mL) solution at 37°C in 5%CO_2 condition.

Upon reaching confluent, the cells were detached by washing with 1 x PBS(-) and adding trypsin-EDTA, and the cells were collected by centrifugation (1000 spins/5 minutes) and appropriately diluted with DMEM medium and subcultured.

Cells after 5 passages were used for transplantation experiments. The number of viable cells which were not stained with trypan blue was counted on Thoma hemocytometer (Thoma deep 0.1 mm ERMA, Tokyo), suspended in Hank's solution and the cell number was adjusted to at 2.5 x 10^6 cells/mL.

[0195]

(2) Production of a cancer-bearing nude mouse and measurement of tumor volume

0.2mL of the prepared KPL-1 cell suspension was subcutaneously transplanted to a nude mouse on the dosal side of the right anterior limb (5 x 10^5 cells/mouse).

Tumor volume after transplantation was assessed by measuring tumor diameter (long axis, short axis and thickness) using calipers and calculated by following equation:

Tumor volume (mm^3) = long axis (mm) x short axis (mm) x thickness (mm)/2

[0196]

(3) Grouping and group constitution

From KPL-1 cancer-bearing nude mice, 24 mice whose tumor volumes were around approximately 80 to 135 mm^3 were selected and divided into 3 groups (8 animals for each group) such that the average tumor volume would be similar. This day was set to Day 0.

The constitution of the test groups is as shown in Table 10. That is, Group I: a group with no treatment, Group II: a group receiving *B. longum* 105A/pSP3B-TNF alpha, Group III: a group receiving *B. breve*/pSP3B-TNF alpha.

[0197]

Table 10: Group constitution

Group	Given substance	Dosage	Number of dosage (times/day)	Administration date (Day)	
Group I	—	—	—	—	8
	—	—	—	—	
Group II	B. longum 105A/pSP3B-TNF alpha	0.2 mL/body/time	2	1, 4, 8, 11	8
	Maltose	200 mg/body/day	2	1～21	
Group III	B. breve/pSP3B-TNF alpha	0.2 mL/body/time	2	1, 4, 8, 11	8
	Maltose	200 mg/body/day	2	1～21	

[0198]

(4) Culturing of bacteria and preparation of bacterial suspension for administration

Culturing of bacteria

The glycerin stocks of the bifidobacteria *B. longum* 105A/pSP3B-TNF alpha prepared in Production Example 4 and *B. breve*/pSP3B-TNF alpha prepared in Production Example 7 were inoculated at 1% to APS-2S-2.5SE (75μg/mL spectinomycin) liquid media, cultured at 37°C for 23.5 hours in anaerobic condition (activating culture solution). Next, the activating culture solution was inoculated at

1% to 20mL of APS-2S-2.5SE (75μg/mL spectinomycin) liquid medium, cultured at 37°C for 18 hours in anaerobic condition (main culture solution).

[0199]

Preparation of cultured viable cells for administration (*B. longum* 105A/pSP3B-TNF alpha)

10mL of themain culture solution obtained as above was measured by a measuring pipette and added to a conical tube containing 40mL of well-cooled PBS buffer, gently mixed by inversion, and then centrifuged in a centrifuge cooled at 4°C, at 8000 rpm for 10 minutes. After centrifugation, the supernatant was removed and 40mL of fresh PBS buffer was added and gently mixed by a vortex. This manipulation was repeated four times to wash the cells. The washed cells were suspended in 5mL PBS buffer to give a cultured viable cells for administration.

[0200]

Preparation of cultured viable cells for administration (*B. breve*/pSP3B-TNF alpha)

10mL of the main culture solution obtained as above was measured by a measuring pipette and added to a conical tube containing 40mL of well-cooled PBS buffer, gently mixed by inversion, and then centrifuged in a centrifuge cooled at 4°C, at 8000 rpm for 10 minutes. After centrifugation, the supernatant was removed and 40mL of fresh PBS buffer was added and gently mixed by a vortex. This manipulation was repeated four times to wash the cells. The washed cells were suspended in 10mL PBS buffer to give cultured viable cells for administration.

[0201]

(5) Administration of the bacterium and maltose

Administering the bacterium

For Group II and Group III, 0.2mL per mouse of each cultured viable cells (Group II :*B. longum* 105A/pSP3B-TNF alpha, Group III :*B. breve*/pSP3B-TNF alpha) was administered intravenously twice a day (AM/PM), at a pace of twice a week (Day 1, 4, 8, 11), for two weeks. The cultured viable cells were administered in the administered total volume of 1.6mL, i.e., the total cell number of 3.1×10^9 cfu/mouse for *B. longum* 105A/pSP3B-TNF alpha, and 4.8×10^9cfu/mouse for *B. breve*/pSP3B-TNF alpha. The number of administered viable cells was measured as follows.

[0202]

Measuring viable cell number

The cultured viable cells were diluted 10^6 times with an anaerobic dilutant, 100μL of which was smeared to three BLFS plates each and cultured in anaerobic condition in a sealed vessel (Anaero Pac Rectangular jar, MITSUBISHI GAS CHEMICAL, INC.) with a deoxygenating/carbon dioxide-generating agent in an incubator at 37°C for three days. For each plate in which colonies of 30 to 300 were detected, the number of the cells administered was calculated by the formula below. Number of the cells administered (cfu) = number of colonies (a) x dilution ratio at the time of being smeared to the plate (b) x conversion coefficient for 1mL of cultured viable cells (c) x dosage (mL)

(a): (P1+P2+P3)/3 [average number of colonies of 3 plates (P1,P2,P3)]

(b): x 10^6 [10^6 times dilution]

(c): x 10 [smeared 100μL per plate]

[0203]

Administering maltose

For Group II and III, 1mL of 10% maltose solution was administered intraperitoneally as carbohydrate source twice a day (200mg/body/day). Administration period was for 21 days from the day of administering the cultured viable cells (Day 1 - 21).

[0204]

(6) Confirming tumor-growth suppressing effect

For all mice, tumor diameter was measured before the initiation of the treatment (at grouping) and for 22 days after the initiation of the treatment, at frequency of once in 3 to 4 days, to confirm the effect against tumor growth.

The average tumor volume ± SD for each group of mice was calculated, and antitumor effect was assessed using relative tumor volume ratio to the control group (Group I) [T/C (%)] as an index. Also, statistical analyses (comparison between two groups: t-test) between Group I and Group II and between Group I and Group III were performed.

The tumor volume for each group (average ± SD) is shown in Table 11 below.

Chronological variation of tumor volume at the time was also shown in Fig. 15.

[0205]

Table 11: Average tumor volume of each group

Group / Given cell	Number of animals	Tumor volume (mm3) after grouping (Day0)								T/C (%)#1 at Day22	Two tailed t-test (p-value) Group I vs
		Measurement date (Day)	0	3	7	10	14	18	22		
一) No treatment	8	Average	107.2	168.6	284.4	426.5	658.3	1347.7	2128.8	—	—
		S.D.	19.6	33.0	52.1	139.0	248.3	647.2	1040.1		
二) B. lonum 105A /pSP3B-TNF alpha	8	Average	105.9	146.7	196.6	274.4	420.0	690.2	1028.8	48.3	0.021
		S.D.	18.1	23.6	33.8	64.7	127.5	225.9	348.6		
三) B. breve /pSP3B-TNF alpha	8	Average	105.5	142.4	151.7	181.9	201.6	337.3	579.4	27.2	0.004
		S.D.	18.6	48.8	56.7	64.5	61.5	146.6	292.2		

#1:T/C(%)= Average tumor volume of Group II or Group III/ Average tumor volume of Group I x 100

[0206]

In either group receiving *B. longum* 105A/pSP3B-TNF alpha or *B. breve*/pSP3B-TNF alpha, a significant decrease in tumor volume was observed compared with untreated group.

[0207]

Working Example 8: Measurement of antitumor effect of *B. longum* 105A/pSP3B-TNF alpha

We measured the antitumor effect of *B. longum* 105A/pSP3B-TNF alpha prepared in Production Example 4 in concomitant use with adriamycin.

(1) Culturing of the transplant tumor cells

Human breast cancer cell line KPL-1 cell was cultured in DMEM medium supplemented with 10% (v/v) FBS and 0.1% (v/v) penicillin (50000U/mL)/ streptomycin (50mg/mL) under the condition at 37°C in 5%CO_2.

Upon reaching confluent, the cells were detached by washing with 1 x PBS(-) and adding trypsin-EDTA, and the cells were collected by centrifugation (1000 spins/5 minutes) and appropriately diluted with DMEM medium and subcultured.

Cells after 5 passages were used for transplantation experiments. The number of viable cells which were not stained with trypan blue was counted on Thoma hemocytometer (Thoma deep 0.1 mm ERMA, Tokyo), suspended in Hank's solution and the cell number was adjusted to at 2.5 x 10^6 cells/mL.

[0208]

(2) Production of a cancer-bearing nude mouse and measurement of the tumor volume

0.2mL of the prepared KPL-1 cell suspension was subcutaneously transplanted to a nude mouse on the dorsal side of the right anterior limb (5 x 10^5 cells/mouse). Tumor volume after transplantation was assessed by measuring tumor diameter (long axis, short axis and thickness) using calipers and calculated by following equation:

Tumor volume (mm^3) = long axis (mm) x short axis (mm) x thickness (mm)/2

[0209]

(3) Grouping and group constitution

From KPL-1 cancer-bearing nude mice, 18 mice whose tumor volumes were around approximately 80 to 120 mm^3 were selected and divided into 3 groups (6 animals for each group) such that the average tumor volume would be similar. This day was set to be as Day 0.

The constitution of the test groups are as shown in Table 12. That is, Group I: untreated group, Group II: the group receiving adriamycin alone, Group III: the group receiving the combination of bacterium (*B. longum* 105A/pSP3B-TNF alpha) + adriamycin.

[0210]

Table 12: Group constitution

Group	Given substance	Dosage	Number of dosage (times/day)	Administration date (Day)	Number of animals
Group I	Bacterium	—	—	—	6
	Maltose	—	—	—	
	Adriamycin	—	—	—	
Group II	Bacterium	—	—	—	6
	Maltose	—	—	—	
	Adriamycin	5 mg/kg	1	0 *	
Group III	Bacterium	0.2 mL/body/time	2	1, 5, 8, 12	6
	Maltose	200 mg/body/day	2	1 to 20	
	Adriamycin	5 mg/kg	1	0 *	

[0211]

(4) Culturing of the bacterium (*B. longum* 105A/pSP3B-TNF alpha)

The glycerin stock of the *Bifidobacterium B. longum* 105A/pSP3B-TNF alpha prepared in Production Example 4was inoculated at 1% to APS-2S-2.5SE (75μg/mL spectinomycin) liquid medium, cultured at 37°C for 23.5 hours in anaerobic condition (activating culture solution). Next, the activating culture solution was inoculated at 1% to 20mL of APS-2S-2.5SE (75μg/mL spectinomycin) liquid medium, cultured at 37°C for 18 hours in anaerobic condition (main culture solution).

[0212]

Preparation of cultured viable cells for administration

5mL of the main culture solution above was measured by a measuring pipette and added to a conical tube containing 20mL of well-cooled PBS buffer, gently mixed by inversion, and then centrifuged in a centrifuge cooled at 4°C, at 8000 rpm for 10 minutes. After centrifugation, the supernatant was removed and 20mL of fresh PBS

buffer was added and gently mixed by a vortex. This manipulation was repeated four times to wash the cells. The washed cells were suspended in 2.5mL PBS buffer to give a cultured viable cells for administration.

[0213]

(5) Administration of the bacterium, maltose and adriamycin

Administering the bacterium

For Group III, 0.2mL per mouse of cultured viable cells (test drug) was administered intravenously twice a day (AM/PM), twice a week (Day 1, 5, 8, 12). The cultured viable cells were administered in the total administered volume of 1.6mL, i.e., the total cell number of 3.0 x 10^9cfu/mouse. The number of administered viable cells was measured as follows.

[0214]

Measuring viable cell number

The cultured viable cells were diluted 10^6 times with an anaerobic dilutant, 100μL of which was smeared to three BLFS plates each and cultured in anaerobic condition in a sealed vessel (Anaero Pac Rectangular jar, MITSUBISHI GAS CHEMICAL, INC.) with a deoxygenating/carbon dioxide-generating agent in an incubator at 37°C for three days. For each plate in which colonies of 30 to 300 were detected, the number of the cells administered was calculated by the formula below. Number of the cells administered (cfu) = number of colonies (a) x dilution ratio at the time of being smeared to the plate (b) x conversion coefficient for 1mL of cultured viable cells (c) x dosage (mL)

(a): (P1+P2+P3)/3 [average number of colonies of 3 plates (P1,P2,P3)]

(b): x 10^6 [10^6 times dilution]

(c): x 10 [smeared 100μL per plate]

[0215]

Administering maltose

For Group III, 1mL of 10% maltose solution was administered intraperitoneally as carbohydrate source twice a day (200mg/body/day). Administration period was for 20 days from the day of administering the cultured viable cells (Day 1 - 20).

Administering adriamycin

For Group II and Group III, 0.1mL adriamycin solution (1.0mg/mL) was administered intravenously to mice only on a day before the first administration of bacterium (Day0).

[0216]

(6) Confirming tumor-growth suppressing effect

For all mice, tumor diameter was measured before the initiation of the treatment (at grouping) and for 21 days after the initiation of the treatment, at frequency of once in 3 to 4 days, to confirm the effect against tumor growth.

The average tumor volume ± SD for each group of mice was calculated, and antitumor effect was assessed using relative tumor volume ratio to the control group (Group I) [T/C (%)] as an index. Also, in order to assess the antitumor ability of the present bacterium secreting TNFα, a statistical analysis (comparison between two groups: t-test) between Group II and Group III was performed.

The tumor volume for each group (average ± SD) is shown in Table 13 below.

Chronological variation of tumor volume at the time was also shown in Fig. 16.

[0217]

Table 13: Average tumor volume of each group

Group / Given cell	Number of animals	Tumor volume (mm3) after grouping (Day0)								T/C (%)#2 at Day21	Two tail t-test (p-value)
		Measurement date (Day	0	4	7	11	15	19	21		
一) No treatment	8	Average	100.3	156.5	238.5	347.4	613.5	1002.2	1337.0	–	–
		S.D.	13.8	44.4	77.5	157.2	274.9	561.6	726.0		–
二) Receiving adriamycin#1	8	Average	97.7	133.6	145.4	257.9	415.2	625.2	852.6	63.8	0.168
		S.D.	14.3	21.5	25.3	42.5	92.4	137.5	199.0		–
三) Receiving bacterium and adriamycin#1	8	Average	97.8	96.9	100.7	120.4	148.5	220.4	265.0	19.8	0.015
		S.D.	12.6	30.0	29.1	26.8	57.8	57.7	104.6		0.0003

#1: Adriamycin 5.0mg/kg
#2:T/C(%)=Average tumor volume of Group II or Group III/ Average tumor volume of Group I x 100

[0218]

In the group received a concomitant use of *B. longum* 105A/pSP3B-TNF alpha and adriamycin, tumor volume was significantly reduced, not only when compared with untreated group but also when compared with the group receiving adriamycin alone. This means, namely, the concomitant use of adriamycin and *B. longum* 105A/pSP3B-TNF alpha may increase their effects.

[0219]

Production Example 8: Production of a Non-Secretory Human IL-18-Expressing *Bifidobacterium*

Construction of Plasmid phIL18mut-His

We constructed a shuttle vector (*Bifidobacterium* -*E. coli*) having only the human IL-18 located downstream of Hu promoter derived from *Bifidobacterium* but

having no secretory signal. A summary is shown in Fig. 17. Details are as follows.

[0220]

Insert Preparation

We used a plasmid human IL18_opt_in_pUC57 having an artificial DNA of human IL-18 (Accession No: NM_001562, 329th to 799th nucleotide sequence in mature protein coding region) of which codons were optimized for *Bifidobacterium*, and Hu promoter located upstream thereof and Hu terminator located downstream thereof (custom-synthesized by GenScript). Upon synthesizing the artificial DNA, amino acid substitutions were introduced to the mature human IL-18 at 2 sites, i.e., at 7th amino acid (from E to A) and at 54th amino acid (from K to A), to decrease the neutralization with a IL-18-binding protein, and a histidine tag was added to the C-terminal (the amino acid sequence of the mature human IL-18: SEQ ID No: 47).

[0221]

Added to 2μg of the plasmid human IL18_opt_in_pUC57 25unit of BamHI and 15unit of BcuI (both enzymes from Fermentas), which was incubated at 37ºC for 3 hours to allow a complete digestion. After the digestion, the plasmid was electrophoresed on 1% agarose gel for purification (1 x TBE buffer, containing ethidium bromide) to separate DNA fragments. A small fragment of approximately 1kbp was cut out, and DNA was extracted and purified from the agarose gel by a DNA extraction kit (QIAquick Gel Extraction Kit, QIAGEN). Purified DNA fragment (insert) was electrophoresed on 0.8% agarose gel (1 x TBE buffer, containing ethidium bromide) with DNA concentration marker to estimate its concentration.

[0222]

Vector Preparation

The plasmid pCDshuttle was completely digested with BamHI, BcuI, PstI and Bsp119I (all from Fermentas; PstI and Bsp119I has their recognition sites on CD). Reacting conditions were in accordance with the instruction for use of the enzymes. After the digestion, the plasmid was electrophoresed on 1% agarose gel for purification (1 x TBE buffer, containing ethidium bromide) for separation, a large fragment of approximately 3.4kbps was cut out, and DNA was extracted and purified from the agarose gel by a DNA extraction kit (QIAquick Gel Extraction Kit, QIAGEN).

Purified DNA fragment (vector) was electrophoresed on 0.8% agarose gel (1 x TBE buffer, containing ethidium bromide) with DNA concentration marker to estimate its concentration.

[0223]

Cloning

The vector and the insert above were mixed in 1:3 (molar ratio) and ligated (Rapid DNA Ligation Kit, Fermentas). Details were in accordance with the product instruction.

2μL of the ligation reaction solution above was used for transforming *E. coli* TOP10 chemically Competent Cell (Invitorogen). Transforming conditions were in accordance with the product instruction. Transformed *E. coli* colonies were cultured overnight in LB (containing 75μg/mL spectinomycin) liquid medium at 37ºC, from which the plasmid was extracted (QIAprep Spin Miniprep Kit, QIAGEN). The plasmid was named as phIL18mut-His (SEQ ID No: 48).

[0224]

Construction of pSP3B-hIL18mut

We constructed a shuttle vector (*Bifidobacterium* -*E. coli*) having human IL18mut fused to a signal peptide downstream of Hu promoter derived from *Bifidobacterium*. A summary is shown in Fig. 18. Details are as follows.

Insert Preparation

5ng of the plasmid phIL18mut-His was used as template for PCR amplification of hIL18mut coding region by PrimeSTAR® HS Premix (TAKARA BIO, Inc.). IL18 F2 and IL18 R2 primers were used, in which the 15 nucleotides on the 5' side of each primer had a homologous sequence to the vector terminal (Table 14). Primers were designed such that the PCR product would not contain the histidine tag from C-terminal of IL-18. PCR program consisted of 30 cycles of 10 seconds at 98°C, 5 seconds at 55°C, 30 seconds at 72°C, followed by 30 seconds at 72°C.

A part of the PCR product was electrophoresed on 2% agarose gel (1 x TBE buffer, containing ethidium bromide) with DNA concentration marker, confirming a single band of approximately 0.5kbp and estimating its concentration.

[0225]

Vector Preparation

5ng of the plasmid pSP3B-TNFalpha was used as template for PCR amplification of a signal peptide SP3 and vector skeletal by PrimeSTAR® HS Premix (TAKARA BIO, Inc.). The primers vector F3 and vector R2 was used (Table 14), in which the 15 nucleotides on the 5' side of each primer had a homologous sequence to the insert terminal. PCR program consisted of 30 cycles of 10 seconds at 98°C, 5 seconds at 55°C, 4 minutes at 72°C, followed by 30 seconds at 72°C.

A part of the PCR product was electrophoresed on 0.8% agarose gel (1 x TBE buffer, containing ethidium bromide) with DNA concentration marker, confirming a single band of approximately 4kbps and estimating its concentration.

[0226]

Table 14 Primers for constructing pSP3B-hIL18mut

Primers	Sequence (5' -> 3')	PCR product
IL18 F2 primer	TACTTCGGCAAGCTGGC	insert
IL18 R2 primer	GAGCAGAAGGTCATCAATCCTCGTTCTGGACGGTG	insert
vector_F3 primer	GATGACCTTCTGCTCGTAGCG	vector
vector_R2 primer	CAGCTTGCCGAAGTAGGCGATGGTCAGCTTGCC	vector

[0227]

Cloning

100ng of the vector and 40ng of the insert above were ligated by the recombination of terminal sequences using In-Fusion Advantage PCR Cloning Kit (TAKARA BIO, Inc.). At this time, Cloning Enhancer (TAKARA BIO, Inc.) was also added into the reaction solution for concurrently degrading the template plasmid contained within the insert and the vector. Details were in accordance with the product instruction of In-Fusion Advantage PCR Cloning Kit.

[0228]

2μL of the In-Fusion reaction solution above was used for transforming *E. coli* TOP10 chemically Competent Cell (Invitorogen). Transforming conditions were in accordance with the product instruction. Transformed *E. coli* colonies were cultured

overnight in LB (containing 75μg/mL spectinomycin) liquid medium at 37°C, from which the plasmid was extracted (QIAprep Spin Miniprep Kit, QIAGEN). This plasmid was fully sequenced and named as pSP3B-hIL18mut (SEQ ID No: 49).

[0229]

Transformation of *Bifidobacterium*

The plasmid pSP3B-hIL18mut was used for transforming *B. longum* 105A and *B. breve* JCM1192 in a similar method as Production Example 1.

[0230]

Working Example 9: Human IL-18 Protein Expression by Recombinant *Bifidobacterium*

Sample Preparation

The glycerin stocks of the recombinant bifidobacteria *Bifidobacterium longum* 105A/ pSP3B-hIL18mut obtained from Production Example 9 and *Bifidobacterium longum* 105A/ pBEshuttle obtained from Reference Example 4 were inoculated at 1% to APS-2S-2.5SE (75μg/mL spectinomycin) liquid media, cultured at 37°C for 24 hours in anaerobic condition (activating culture solution). Subsequently, the activating culture solution was inoculated at 0.5% to a medium (for each 20mL of APS-2S-2.5SE (75μg/mL spectinomycin) liquid medium 4mL of 1M sodium phosphate buffer (pH6.8) was added), which was cultured at 37°C for 18 hours in anaerobic condition (main culture solution).

[0231]

Bifidobacterium breve JCM1192/ pSP3B-hIL18mut was cultured in a similar method as above, except that themain culture was cultured for 14 hours.

1.3mL of the main culture solution was measured to a tube with a capacity of 1.5mL, centrifuged (14,000rpm for 5 minutes at 4°C), and the supernatant was collected to give a sample for IL-18 measurement.

[0232]

IL-18 Measurement

The protein content of the human IL-18 in each supernatant was measured using Human IL-18 ELISA kit (MBL). As a result, 986pg/mL of IL-18 was detected in *Bifidobacterium longum* 105A/ pSP3B-hIL18 and 1632pg/mL in *Bifidobacterium breve*

JCM1192/ pSP3B-hIL18mut, although none was detected in the mock.

[Industrial Applicability]

[0233]

Introducing the secretory signal peptide of the present invention into an expression cassette enables an efficient secretion of an expressed protein from a transformed bacterium without impairing its physiological activity. Accordingly, the vector of the present invention and the anaerobic microorganism transformed with said vector are capable of more efficiently providing a therapeutic agent to a disease site in an anaerobic disease tissue compared with those of conventional use, thereby being capable of providing a high therapeutic effect.

CLAIMS

[Claim 1] A DNA encoding a secretory signal peptide derived from *Bifidobacterium longum*.

[Claim 2] The DNA encoding a secretory signal peptide according to Claim 1, comprising a DNA sequence according to any one of the nucleotide sequences of SEQ ID No.: 6 to 28, or said sequence in which one or several nucleotide thereof are deleted, substituted or added.

[Claim 3] A secretory signal peptide encoded by the DNA according to Claim 1 or 2.