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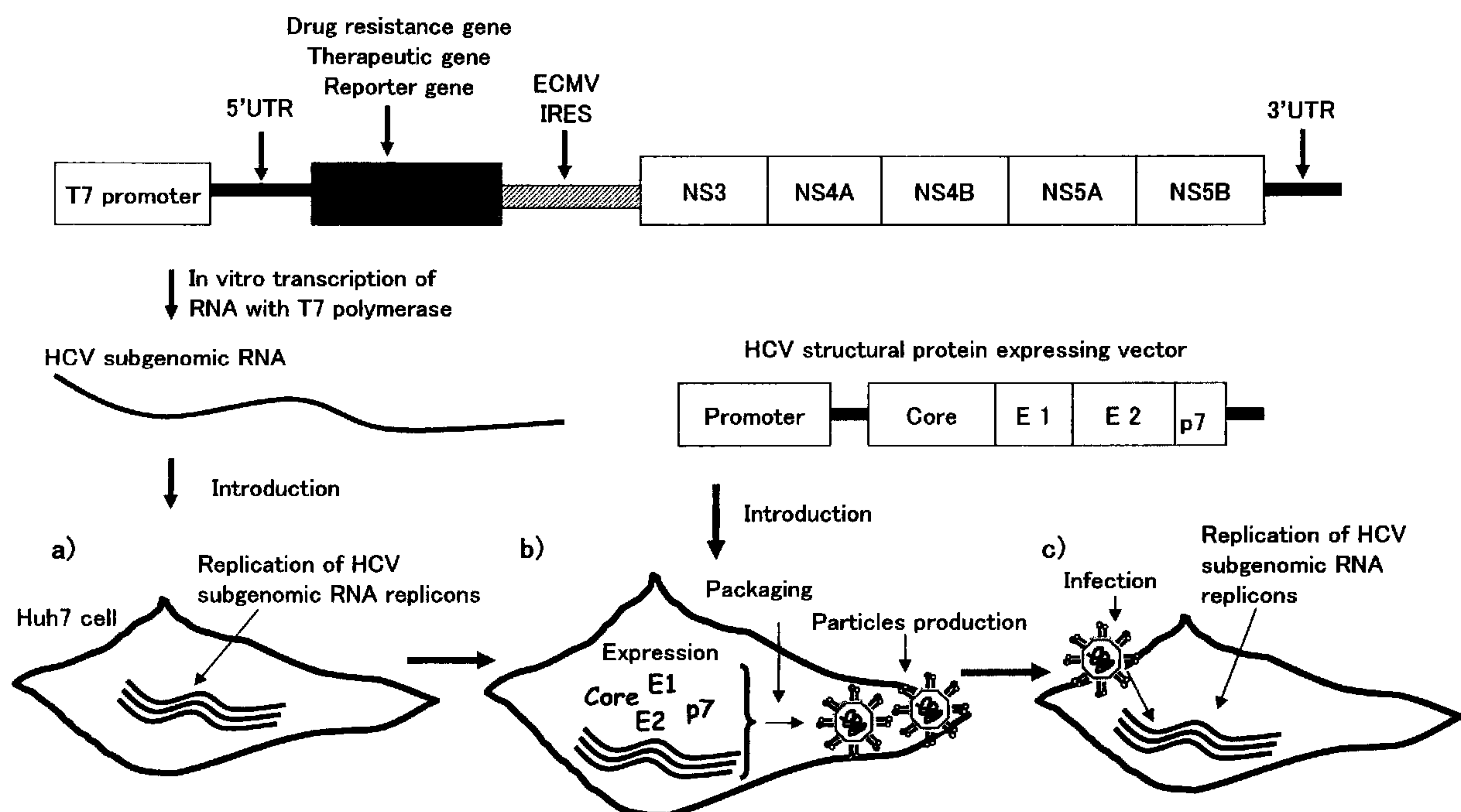
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(54) Titre : NOUVELLE PARTICULE HUMAINE RECOMBINEE DE TYPE DU VIRUS DE L'HEPATITE C ET PROCEDE DE PRODUCTION ASSOCIE

(54) Title: NOVEL RECOMBINANT HUMAN HEPATITIS C VIRUS-LIKE PARTICLE AND METHOD FOR PRODUCING THE SAME



(57) Abrégé/Abstract:

The present invention relates to a method for producing a recombinant hepatitis C virus-like particle comprising the steps of introducing into (i) a cell in which an RNA replicon comprising a nucleotide sequence comprising the 5' untranslated region, the nucleotide sequence coding for the NS3, NS4A, NS4B, NS5A, and NS5B proteins, and the 3' untranslated region of a genome RNA derived from a hepatitis C virus strain autonomously replicates, (ii) a vector expressing the Core, E1, E2, and p7 proteins derived from a hepatitis C virus strain that is the same as or different from that as defined in the above (i), culturing the cell, and recovering the produced virus-like particle, and a recombinant hepatitis C virus particle produced by this method.



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ABSTRACT

The present invention relates to a method for producing a recombinant hepatitis C virus-like particle comprising the steps of introducing into (i) a cell in which an RNA replicon comprising a nucleotide sequence comprising the 5' untranslated region, the nucleotide sequence coding for the NS3, NS4A, NS4B, NS5A, and NS5B proteins, and the 3' untranslated region of a genome RNA derived from a hepatitis C virus strain autonomously replicates, (ii) a vector expressing the Core, E1, E2, and p7 proteins derived from a hepatitis C virus strain that is the same as or different from that as defined in the above (i), culturing the cell, and recovering the produced virus-like particle, and a recombinant hepatitis C virus particle produced by this method.

DESCRIPTION

NOVEL RECOMBINANT HUMAN HEPATITIS C VIRUS-LIKE PARTICLE AND METHOD FOR PRODUCING THE SAME

Technical Field

[0001]

The present invention relates to a human recombinant hepatitis C virus-like particle and a method for producing the same.

Background Art

[0002]

Methods for introducing a gene into an animal cell are roughly classified into physiochemical methods and biological methods. Examples of physiochemical methods include methods such as calcium phosphate coprecipitation, DEAE dextran, lipofection, microinjection, and electroporation. Examples of biological methods include methods using viral vectors.

[0003]

A viral vector method is a method in which a gene is introduced by utilizing the cell invasion mechanism of virus, that is, an infecting ability.

[0004]

Virus-derived structural proteins (nucleocapsid, envelope protein, etc.) exist on the surface of a recombinant viral particle prepared by using a viral vector, which have a mechanism for efficient introduction of a gene so that the virus can infect a cell via a receptor on the cell surface. Therefore, a recombinant viral particle prepared using such a viral vector can be used not only to introduce a gene into an animal cell to generate a cell expressing the gene of interest, but also to perform gene therapy, construct a transgenic animal, and so forth.

[0005]

Viral vectors are grouped into retrovirus vectors, DNA virus vectors, and RNA virus vectors and characterized by the length of a gene that can be introduced, whether the gene is incorporated into the chromosomal genome in a cell, whether the gene can only be introduced into a dividing cell or can also be introduced into a nondividing cell, types of cells that can be infected, cytotoxicity, gene introduction efficiency, and so forth, which depend on the type of the original virus.

[0006]

Retroviruses have a plus-strand RNA as a genome. This RNA has properties characteristic to mRNA of eukaryotic cells, specifically, a methylated cap structure at the 5' end and a polyA tail of about 200 nucleotides at the 3' end. In an infected cell, this RNA is converted to DNA by reverse transcriptase of the virus. Further, the DNA is incorporated into genomic DNA of the host by actions of enzymes encoded by the viral genes. The incorporated DNA is called provirus. A repetitive sequence (long terminal repeat: LTR) occurs at the either end of a provirus, and viral RNA is synthesized by a promoter existing in this sequence. Viral proteins are translated from the synthesized RNA, and a genome-sized RNA is incorporated into the viral particle, which is released out of the cell as a daughter particle.

[0007]

The RNA structure required for production of a viral particle includes LTR at either end, a primer-binding site sandwiched therebetween, a packaging signal, and a polypurine signal. These are essential *cis* factors. On the other hand, genes coding for viral proteins are not essential as *cis* factors, and replication and production of a particle normally occur once viral proteins are supplied within the infected cell.

[0008]

Therefore, to produce a recombinant retrovirus, a vector from which genes encoded by the retrovirus, such as *gag*, *pol*, and *env*, are removed and into which a gene of interest to be expressed is inserted instead (referred to as a retrovirus vector) is prepared, and this vector is introduced into a cell in which viral proteins are supplied (usually referred to as a packaging cell) to prepare a retrovirus particle incorporated with a foreign gene (Non-patent Document 1).

[0009]

Examples of the retrovirus include mouse leukemia virus, feline leukemia virus, baboon type C oncovirus, human immunodeficiency virus, adult T cell leukemia virus, and so forth. Furthermore, examples of those reported as recombinant retrovirus vectors include those based on mouse leukemia virus (Non-patent Document 1), those based on human immunodeficiency virus (Non-patent Document 2), and so forth.

[0010]

A system for production of a recombinant retrovirus consists of two component units, specifically, a retrovirus vector carrying genetic information (a foreign gene of interest) to be introduced and all factors required for packaging and incorporation of the viral genome in *cis* (recombinant retrovirus DNA) and a retrovirus packaging cell that supplies viral proteins encoded by the *gag*, *pol*, and *env* genes. The recombinant retrovirus particle cannot be released by a packaging cell alone into which a recombinant vector expressing the *gag*, *pol*, and *env* genes is introduced.

[0011]

To produce a recombinant retrovirus particle, the *gag*, *pol*, and *env* proteins need to be positioned in *trans*. Therefore, by introducing a retrovirus vector into a packaging cell into which a recombinant vector expressing the *gag*, *pol*, and *env* genes is introduced, a recombinant retrovirus carrying genetic information held in the above-mentioned vector can be produced. Subsequently, when a cell is infected with these viruses, the retrovirus vector will be incorporated into the chromosomal genome in the cell according to the natural retrovirus life cycle.

[0012]

Thus, the retrovirus vector method is a system constructed for the purpose of efficient incorporation of a specific DNA into the chromosomal genome of the host. However, since the location of the gene of interest to be inserted cannot be predicted, possibilities cannot be ruled out that normal gene may be damaged by insertion, genes in the vicinity of the insertion site may be activated, and the foreign gene of interest may be overexpressed or underexpressed. To overcome these problems, development of a transient

expression system using a DNA virus vector that can be utilized as an extrachromosomal gene was promoted.

[0013]

A DNA virus vector is a vector derived from a DNA virus. DNA virus carries DNA in its viral particle as genetic information. This DNA is replicated by repetition of a process of producing a complementary strand using its own DNA as a template by host-derived DNA-dependent DNA replication enzymes at least as a part of catalysts. Examples of DNA virus vectors that can be utilized as an extrachromosomal gene include adenoviral vectors.

[0014]

Human adenovirus has about 36-kb linear double-stranded DNA as a genome, and regions included in this genome are roughly divided into early genes E1, E2, E3, and E4 and late genes L1, L2, L3, L4, and L5. The early genes are primarily involved in virus replication, and the late genes are involved in synthesis of viral structural proteins such as capsid. An adenovirus vector used for introduction of a gene is prepared by replacing the E1 region (divided into E1A and E1B, and all adenovirus promoters are activated by E1A), an early gene, with a desired foreign gene (gene of interest) and proliferated using 293 cells, a cell line that can supply E1A in *trans* (293 cells express E1A). An adenovirus vector deficient in the E1A region cannot be proliferated in a normal cell, which does not express E1A. Since the E3 region is not essential for propagation of virus, it is often removed to increase the insertion size of a foreign gene. Since adenovirus can package a genome up to 105% of the genome size of a wild type in its capsid, a foreign gene of up to 8.1 kb can be inserted by deleting the E1 and E3 regions (Non-patent Document 3).

[0015]

An adenovirus vector can introduce a gene into a nongrowing cell or a growing cell (Non-patent Document 4). Therefore, this method is suitable for *in vivo* gene introduction methods. One of disadvantages of this vector is the generally short gene expression period (in units of week). This is because the adenovirus genome exists only within an extrachromosomal region (episome) and is not replicated or amplified. A second

disadvantage is that the adenovirus commonly used at present causes nonspecific inflammatory reactions and intensifies a cell-mediated immune response against the vector itself. Therefore, it is difficult to perform continuous administration in gene therapy (Non-patent Document 5).

[0016]

Viral vectors based on RNA virus are being developed. RNA virus is replicated by repeating the process of generating a complementary strand using its own RNA as a template by its own RNA-dependent RNA replication enzymes as catalysts.

[0017]

RNA viruses are classified into minus-strand RNA viruses and plus-strand RNA viruses. Representative examples of minus-strand RNA viruses include influenza virus. The influenza virus genome consists of eight minus-strand RNA segments. When influenza virus infects a cell, gene transcription is initiated by proteins in the influenza particle. First, viral RNA polymerase cleaves mRNA of the host cell at a dozen or so nucleotides from the 5'-end cap structure and utilizes the fragments as primers to elongate the RNA strand (plus strand). Viral proteins are translated from this plus-strand RNA. In the replication process, RNA completely complementary to the viral RNA is synthesized, and progeny virus RNA is amplified using this sequence as a template. Then, the viral RNA is packaged together with viral proteins to form a viral particle.

[0018]

Therefore, to produce influenza virus in a cell culture system, proteins encoded by influenza virus are expressed by RNA polymerase II promoters such as, for example, CMV and CAG promoters, viral RNA is expressed by RNA polymerase I promoters, promoters without a cap structure and polyA, such as, for example, rRNA gene promoters, and the viral RNA is packaged together with viral proteins in the cell to form a viral particle (Non-patent Document 6). However, the amount of virus to be produced is not specified, and this technique has not been established as a technique that can be utilized in view of production to a satisfactory extent.

[0019]

Examples of viruses classified as plus-strand RNA viruses include *Sindbis* virus and hepatitis C virus. The genome RNA of a plus-strand RNA virus also functions as messenger RNA (hereinafter referred to as “mRNA”) at the same time and can produce proteins required for replication and particle formation depending on the translation function of the host cell. In other words, the genome RNA of the plus-strand RNA virus itself has a transmitting ability.

[0020]

Viral vectors derived from *Sindbis* virus has a basic structure of the genome RNA from which the structural gene region involved in the virus structure is deleted and in which a gene group for proteins required for virus transcription and replication are retained and RNA in which a desired foreign gene is ligated to the downstream of the transcription promoter. When such RNA or cDNA transcribed to this RNA is introduced into a cell, autonomous replication of RNA vector including the foreign gene and transcription of the foreign gene located downstream of the transcription promoter occur, and a foreign gene product of interest is expressed in the cell. Further, a complex that has an infecting ability but not a transmitting ability can be prepared by allowing a cDNA unit expressing structural genes (helper) and a cDNA unit expressing the above-mentioned RNA vector to coexist in a packaging cell (Non-patent Document 7).

[0021]

Since *Sindbis* virus uses 67-kDa high-affinity laminin receptor (LAMR) as a receptor and infects nerve cells in high efficiency, *Sindbis* virus vector draws attention as a system for introducing a gene specifically to nerves (Non-patent Document 8). However, since it has been shown that infection by *Sindbis* virus induces apoptosis of the host cell (Non-patent Document 9), toxicity is concerned.

[0022]

The genome of hepatitis C virus (HCV) is plus-strand single-stranded RNA of about 9600 nucleotides. This genome RNA comprises the 5' untranslated region (also expressed as 5'NTR or 5'UTR), the translated region including a structural region and a nonstructural region, and the 3' untranslated region (also expressed as 3'NTR or 3'UTR). Structural

proteins of HCV are encoded in the structural region, and multiple nonstructural proteins are encoded in the nonstructural region.

[0023]

Such structural proteins (Core, E1, E2, and p7) and nonstructural proteins (NS2, NS3, NS4A, NS4B, NS5A, and NS5B) of HCV are translated as a continuous polyprotein from the translated region, subjected to limited digestion by protease, released, and produced. Of these structural proteins and nonstructural proteins (i.e., viral proteins of HCV), Core is the core protein. E1 and E2 are envelope proteins. Nonstructural proteins are viral proteins involved in replication of the virus itself. NS2 is known to have a metalloprotease activity, and NS3 is known to have a serine protease activity (1/3 on the side of the N terminus) and a helicase activity (2/3 on the side of the C terminus). Furthermore, it is also reported that NS4A is a cofactor for the protease activity of NS3, and that NS5B has an RNA-dependent RNA polymerase activity.

[0024]

It has been revealed that HCV is classified into many types depending on the genotype or the serotype. According to the phylogenetic analysis method by Simmonds *et al.* using nucleotide sequences of HCV strains, which is a currently mainstream HCV genotype classification method, HCV is classified into six types including genotypes 1a, 1b, 2a, 2b, 3a, and 3b, and these are further subdivided into several subtypes. Furthermore, the nucleotide sequences of the full-length genomes of some genotypes of HCV have been determined (Non-patent Documents 10 to 13).

[0025]

An HCV particle is captured by sulfated polysaccharides on the cell surface, binds to a high-affinity receptor via envelope proteins, and is taken up into the endosome by endocytosis. Then, the virus membrane and the endosome membrane fuse, and the nucleocapsid invades the cytoplasm. Translation of the naked viral genome is initiated by Internal Ribosome Entry Site (IRES). Translation and cleavage of a protein occur on the endoplasmic reticulum membrane. The Core protein, the E1 and E2 proteins, and viral RNA replicated on the endoplasmic reticulum are assembled to form a viral particle. Then, the

particle buds into the endoplasmic reticulum lumen. It is thought that the particle that has budded is released out of the cell through the Golgi apparatus.

[0026]

Recently, preparation of an HCV subgenomic RNA replicon as HCV-derived RNA having an autonomous replication ability (Patent Documents 1 and 2 and Non-patent Documents 14 to 16) has enabled analysis of the HCV replication mechanism using cultured cells. This HCV subgenomic RNA replicon is obtained by replacing the structural proteins existing downstream of HCV IRES in the 5' untranslated region of HCV genomic RNA with the neomycin resistance gene and EMCV-IRES ligated to the downstream thereof. It has been demonstrated that, when introduced into human liver cancer cell Huh7 and cultured in the presence of neomycin, this RNA replicon autonomously replicates in the Huh7 cell. Furthermore, it has been demonstrated that some HCV subgenomic RNA replicons autonomously replicate not only in Huh7 but also in cells such as human cervical cancer cell HeLa or human liver cancer cell HepG2 (Patent Document 3). Furthermore, Patent Document 2 proposes production of HCV virus particle utilizing the full-length HCV genome when a recombinant HCV is used as a vector for gene therapy.

[Patent Document 1] JP Patent Publication (Kokai) No. 2002-171978 A

[Patent Document 2] JP Patent Publication (Kokai) No. 2001-17187 A

[Patent Document 3] International Patent Publication WO2004/104198

[Non-patent Document 1] Mann, R. *et al.*, Cell, 33 (1983) p153-59

[Non-patent Document 2] Simada, T *et al.*, J Clin Invest. 88 (1991) p1043-47

[Non-patent Document 3] Betta, A *et al.*, Proc. Nati. Acad. Sci. USA 91 (1994) p8802-06

[Non-patent Document 4] Burden, S & Yarden, Y., Neuron, 18 (1997) p847-55

[Non-patent Document 5] Crystal, R.G Science, 270, (1995) p404-10

[Non-patent Document 6] Neumann, G. & Kawaoka, Y., Virology 287 (2001) p243-50

[Non-patent Document 7] Berglund, P *et al.*, Biotechnology, 11 (1993) p916-920

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- [Non-patent Document 14] Blight *et al.*, Science, 290 (2000) p1972-74
- [Non-patent Document 15] Friebe *et al.*, J. Virol., 75 (2001) p12047-57
- [Non-patent Document 16] Kato, T. *et al.*, Gastroenterology, 125 (2003) p1808-17

Disclosure of the Invention

[0027]

HCV has not actually been developed as a viral vector like those of retrovirus, adenovirus, influenza virus, and *Sindbis* virus. If such an HCV vector is developed, genes can be introduced specifically into cells of tissues of the liver or the like. In this case, to ensure safety to a higher extent, it is desirable that the HCV vector infects cells but does not have a transmitting property.

[0028]

An object of the present invention is to develop a recombinant hepatitis C virus (HCV)-like particle that is usable as such a vector as described above. Furthermore, another object of the present invention is to provide a method for producing this HCV-like particle efficiently.

[0029]

The inventors of the present invention attempted to allow cultured cells to produce a recombinant HCV-like particle that appears to be industrially useful in view of safety, convenience, and applicability. First, the HCV genome was divided into a vector expressing the HCV structural proteins and a vector including the genes involved in replication. A desired foreign gene and/or IRES (Internal Ribosome Entry Site) can be included in the latter vector.

[0030]

The inventors of the present invention constructed a vector obtained by cloning DNA including a desired foreign gene, the IRES sequence, and the genes involved in replication of HCV into the downstream of the T7 promoter and synthesized *in vitro* an HCV subgenomic RNA replicon including the foreign gene sequence using T7 polymerase. This RNA replicon was introduced into a cultured animal cell to obtain a cell strain in which the HCV subgenomic RNA replicon was replicated.

[0031]

Subsequently, they found a system that can introduce a vector highly expressing the HCV structural proteins into the cell strain in high efficiency and introduced it into cells carrying HCV subgenomic RNA replicons of various genotypes. As a result, by expressing the HCV structural proteins in cells, they successfully found combinations with which the HCV subgenomic RNA replicon can be packaged in a viral particle.

[0032]

Furthermore, the inventors of the present invention confirmed that a recombinant HCV-like particle produced by the method of the present invention infects cells and that a cell infected by the recombinant HCV does not have a transmitting property, producing no daughter viral particle. Due to such characteristics, the recombinant HCV particle of the present invention can be used as a vector for introduction of a foreign gene or for gene therapy.

[0033]

Specifically, the present invention is characterized by the following characteristics in summary.

[0034]

As a first aspect, the present invention provides a method for producing a recombinant hepatitis C virus particle, comprising the steps of introducing into:

(i) a cell carrying an RNA replicon having a nucleotide sequence comprising the 5' untranslated region, the nucleotide sequence coding for the NS3, NS4A, NS4B, NS5A, and NS5B proteins and the 3' untranslated region of genome RNA derived from a hepatitis C virus strain,

(ii) a vector expressing the Core, E1, E2, and p7 proteins derived from a hepatitis C virus strain that is the same as or different from the strain as defined in the above (i), culturing the cell, and recovering the produced recombinant hepatitis C virus particle.

[0035]

As one embodiment, the hepatitis C virus strain of the above (i) and (ii) is at least one strain independently selected from the group consisting of virus strains of genotypes 1a, 1b, 2a, 2b, 3a, and 3b.

[0036]

In another embodiment, the hepatitis C virus strain of the above (i) and (ii) is at least one strain independently selected from the group consisting of virus strains of genotypes 1b and 2a.

[0037]

Furthermore, in another embodiment, the hepatitis C virus strain of the above (i) is a virus strain of genotype 1b.

[0038]

In a preferred embodiment, the above-mentioned virus strain of genotype 1b is the con1 strain or a strain derived therefrom.

[0039]

In another embodiment, the hepatitis C virus strain of the above (ii) is a virus strain of genotype 2a.

[0040]

In a preferred embodiment, the above-mentioned virus strain of genotype 2a is the JFHI strain or a strain derived therefrom.

[0041]

In yet another embodiment, the above-mentioned RNA replicon can further include at least one IRES sequence.

[0042]

In yet another embodiment, the above-mentioned RNA replicon can further include at least one foreign gene.

[0043]

In a preferred embodiment, the above-mentioned IRES and the above-mentioned foreign gene can be positioned between the above-mentioned 5' untranslated region and the above-mentioned NS3.

[0044]

In yet another embodiment, the above-mentioned cell is an animal cell.

[0045]

In a preferred embodiment, the above-mentioned animal cell is a mammal cell.

[0046]

Examples of the above mammal cell include Huh7, HepG2, and established cell lines derived from these cells.

[0047]

In yet another embodiment, the above-mentioned expression vector is a viral vector.

[0048]

In a preferred embodiment, the above-mentioned viral vector is a vaccinia virus vector.

[0049]

Viral particles can be proliferated by allowing the recombinant hepatitis C virus particle produced and recovered by the above-described method of the present invention to infect HCV-susceptible cells such as hepatic or lymphoid cells. Such processes are encompassed in the scope of the present invention includes.

[0050]

According to a second aspect, the present invention also provides a recombinant hepatitis C virus particle produced by the above-described method of the present invention and characterized by having an infecting ability but not a transmitting ability.

[0051]

In one embodiment thereof, a foreign gene is introduced into the above-mentioned recombinant hepatitis C virus particle in an expressible manner.

[0052]

In another embodiment, the above-mentioned recombinant hepatitis C virus particle is a vector.

[0053]

In the present invention, one of preferred methods for producing a recombinant hepatitis C virus particle is a method for producing a recombinant hepatitis C virus particle, wherein said method comprises the steps of introducing into

(i) a cell in which an RNA replicon consisting of a nucleotide sequence comprising at least the 5' untranslated region, the nucleotide sequence coding for the NS3, NS4A, NS4B, NS5A, and NS5B proteins, and the 3' untranslated region of a genome RNA derived from the hepatitis C virus con1 strain, or an RNA replicon further containing at least one foreign gene and/or at least one IRES sequence in addition to the nucleotide sequence, autonomously replicates (ii) a vaccinia virus vector expressing the Core, E1, E2, and p7 proteins of hepatitis C virus derived from the JFH1 strain, culturing the cell, and recovering the produced recombinant hepatitis C virus particle.

[0054]

Furthermore, in the present invention, a preferred recombinant hepatitis C virus particle is produced by the above-described preferred method.

[0055]

The present invention further includes the following [1] and [2].

[0056]

[1] A method for producing a recombinant hepatitis C virus-like particle comprising the steps of introducing into

(i) a cell carrying a RNA replicon comprising a nucleotide sequence comprising the 5' untranslated region, the nucleotide sequence coding for the NS3, NS4A, NS4B, NS5A, and NS5B proteins, and the 3' untranslated region of a genome RNA derived from at least one virus strain selected from the group consisting of hepatitis C virus strains of genotypes 1a, 1b, 2a, 2b, 3a, and 3b,

(ii) a vector expressing the Core, E1, E2, and p7 proteins derived from at least one virus strain selected from the group consisting of hepatitis C virus strains of genotypes 1a, 1b, 2a, 2b, 3a,

and 3b that is the same as or different from the hepatitis C virus strain as defined in the above (i),

culturing the cell, and recovering the produced virus-like particle.

[0057]

It is preferable in this method that the hepatitis C virus strain of genotype 1b as defined in the above-mentioned (i) is the con1 strain, and that the hepatitis C virus strain of genotype 2a as defined in the above-mentioned (i) is the JFH1 strain.

[0058]

Furthermore, it is also preferable in this method that the hepatitis C virus strain of genotype 1a as defined in the above-mentioned (ii) is the H77c, 1, H, or HC-J1 strain.

[0059]

It is also preferable in this method that the hepatitis C virus strain of genotype 1b as defined in the above-mentioned (ii) is the J1, con1, TH, J, JT, and BK strain.

[0060]

It is also preferable in this method that the hepatitis C virus strain of genotype 2a as defined in the above-mentioned (ii) is the JFH1, HC-J6, JCH1, or J6CF strain.

[0061]

It is also preferable in this method that the hepatitis C virus strain of genotype 3a as defined in the above-mentioned (ii) is the NZL1, K3a/650, 452, or E-b1 strain.

[0062]

It is also preferable in this method that the hepatitis C virus strain of genotype 3b as defined in the above-mentioned (ii) is the Tr strain.

[0063]

Furthermore, it is preferable in this method that the vector of the above-mentioned (ii) is a vaccinia virus vector or an EF-1 α promoter carrying vector.

[0064]

Furthermore, it is preferable in this method that the above-mentioned RNA replicon further comprises at least one internal ribosome entry site (IRES) sequence and/or at least one foreign gene.

55232-7

[0065]

It is preferable that the IRES sequence and/or the foreign gene is positioned between the above-mentioned 5' untranslated region and the sequence coding for the above-mentioned NS3 protein.

5 [0066]

In this method, the above-mentioned cell is preferably an animal cell. Preferred examples of the animal cell include the Huh7 cell, the HepG2 cell, and established cell lines derived from these cells.

[0067]

10 [2] A recombinant hepatitis C virus-like particle produced by the above-described method [1] that has an infecting property but not a transmitting ability.

[0068]

A recombinant infectious HCV-like particle in which an HCV subgenomic RNA including a desired foreign gene is packaged and which does not have a transmitting
15 property and a production method thereof can be provided by the present invention. Since such a recombinant infectious HCV-like particle has an advantage of not having a transmitting property, it can be used for gene introduction (e.g., gene therapy), in particular, into hepatic or lymphoid cells or tissues or can be used as a viral vector for producing a transgenic animal or as an attenuated vaccine.

20 [0068a]

Specific aspects of the invention include:

- a method for producing a recombinant hepatitis C virus-like particle comprising, introducing a vaccinia virus vector or an EF-1 α promotor carrying vector into a cell, (i) wherein said cell carries a subgenomic RNA replicon comprising a nucleotide
25 sequence comprising the 5' untranslated region, the nucleotide sequence coding for the NS3, NS4A, NS4B, NS5A, and NS5B proteins, and the 3' untranslated region of a genome RNA

55232-7

derived from con1 strain of hepatitis C virus and wherein said subgenomic RNA replicon does not comprise HCV structural genes, and (ii) wherein said vaccinia virus vector or said EF-1 α promoter carrying vector expresses the Core, E1, E2, and p7 proteins derived from at least one virus strain selected from the group consisting of hepatitis C virus strains of genotype 1a, 1b, 2a, 2b, 3a, and 3b different from the hepatitis C virus strain as defined in the (i), culturing the cell, and recovering the produced virus-like particle; and

- a recombinant hepatitis C virus-like particle produced by the method of the invention, which has an infecting property but not a transmitting ability.

Brief Description of the Drawings

10 [0069]

Figure 1 is a schematic view of an embodiment of the present invention, which shows production processes of a recombinant HCV-like particle. a): HCV subgenomic RNA replicons are replicated in the Huh7 cell into which the HCV subgenomic RNA replicon is introduced. A viral particle is not produced. b): In the cell of a) into which an HCV structural protein expressing vector is introduced, virus-like particles in which the HCV subgenomic RNA replicon is packaged are produced utilizing expressed HCV structural

proteins. c): In a cell infected by the virus-like particle produced in b), HCV subgenomic RNA replicon are replicated, but no daughter viral particle is produced.

Figure 2 shows structural drawings of HCV genomic RNA and cDNA of HCV subgenomic RNA. The upper diagram and the middle diagram show pJFH1 and pSGR-JFH1, respectively, prepared from HCV of genotype 2a. The lower diagram shows I389/NS3-3'/wt prepared from HCV genotype 1b. The symbols in the figure denote as follows: T7, T7 RNA promoter; 5'UTR, 5' untranslated region; Core, Core protein; E1 and E2, envelope proteins; p7, p7 protein; NS2, NS3, NS4A, NS4B, NS5A, and NS5B, nonstructural proteins; 3'UTR, 3' untranslated region; AgeI, PmeI, and XbaI, cleavage sites of restriction enzymes *AgeI*, *PmeI*, and *XbaI*; EMCV IRES, internal ribosome entry site of encephalomyocarditis virus.

Figure 3 shows maps of vectors for expressing the HCV structural proteins of the present invention. Specifically, the upper diagram shows pGAGC-p7JFH1, a plasmid clone prepared by inserting the JFH structural region genes into the downstream of the CAG promoter. The lower diagram shows the structure of pEF4C-p7JFH1, a plasmid clone prepared by inserting the JFH structural region genes into the downstream of the elongation factor 1 α promoter sequence. The symbols in the figure denote as follows: CAG, CAG promoter; pA, additional polyA sequence; *EcoRI*, cleavage site of restriction enzyme *EcoRI*; EF-1 α , elongation factor 1 α promoter; BGH pA, additional polyA sequence of bovine growth factor.

Figure 4 shows maps of the HCV structural genes inserted into vectors pDIsHJFHst, pDIsH77st, pDIsJ1st, pDIsJ1(c)/JFH(E1-p7)st, and pDIsJFH(c)/J1(E1-p7)st. Differences in virus strains from which the vectors are derived are represented by shaded areas in the frame;

Figure 5 shows graphs showing the amount of HCV replicon RNA (A) and the amount of the HCV Core protein (B) in each fraction obtained by introducing pEF4C-p7JFH1 into a replicon carrying cell strain IH4.1 and fractionating the cell culture supernatant (sup) by a sucrose density gradient. □, Experiment 1; ♦, Experiment 2.

Figure 6 shows graphs showing the amount of the HCV Core protein (vertical axis) in each fraction (horizontal axis) obtained by allowing DIsJFHst, a vaccinia virus vector, to infect a replicon carrying cell strain 5-15 and fractionating the cell culture supernatant (sup) by

a sucrose density gradient. The closed circle represents the HCV Core protein, and the closed square represents results using an NP40-treated culture supernatant. Experiment 1 shows results of only untreated culture (Figure 6 A), and Experiment 2 shows results of untreated and NP40-treated culture supernatants (Figure 6 B).

Best Mode for Carrying Out the Invention

[0070]

1. Definition

The terms used in the present specification have the following meanings.

[0071]

The term “RNA replicon” refers to RNA that is prepared by modifying the HCV virus genome and has an autonomously replicating ability.

[0072]

The term “autonomously replicating ability” means an ability of autonomously reproducing copies of a nucleic acid (i.e., replication) in a cell like plasmid DNA.

[0073]

The term “infecting ability” or “infecting property” refers to an ability of introducing a nucleic acid and the like within a virus into a cell due to abilities of adhering to a cell, fusing with a cell membrane, and the like.

[0074]

The term “recombinant hepatitis C virus” means a virus obtained by changing properties of the original HCV virus qualitatively/quantitatively using genetic engineering techniques. Examples thereof include a virus capable of expressing a foreign gene in addition to genes expressed by the original virus, a virus deficient in a transmitting property or an ability of replicating a virus genome of the original virus, and so forth. In the broad sense, viruses obtained by recombination of genes between different types or subtypes of the same virus are included.

[0075]

The term “transmitting property ” or “transmitting ability” means an ability of forming an infecting particle or a complex similar thereto and transmitting it into another cell after introduction of a nucleic acid into a cell by infection or an artificial technique and replication of the nucleic acid existing in the cell.

[0076]

“Core” is a core structural protein of HCV.

[0077]

“E1” and “E2” are both envelope structural proteins.

[0078]

“NS” refers to a nonstructural protein of HCV, which is involved in replication of the virus itself. “NS2” has a metalloprotease activity. “NS3” has a serine protease activity (1/3 on the N terminus side) and a helicase activity (2/3 on C terminus side). “NS4A” is a cofactor for the protease activity of NS3. The function of “NS4B” is not clear. “NS5A” is thought to have an activity of regulating transfer of information of the host cell. “NS5B” has an RNA-dependent RNA polymerase activity.

[0079]

The term “IRES sequence” means an internal ribosome entry site, which can bind the ribosome within RNA to initiate translation.

[0080]

The expression “in an expressible manner” means a state that a gene of interest can be transcribed and translated by regulatory sequences such as a promoter and an enhancer.

[0081]

2. HCV subgenomic RNA replicon carrying cell

The wild type HCV genome consists of about 9.6-kb single-stranded RNA coding for a precursor protein of about 3000 amino acids. The HCV genome is constituted by the 5' untranslated region (5'UTR), Core, E1, E2, p7, NS2, NS3, NS4A, NS4B, NS5A, NS5B, and the 3' untranslated region (3'UTR) in this order. The HCV subgenomic RNA replicon used in the method of the present invention includes modified RNA constituted by the 5' untranslated region, NS3, NS4A, NS4B, NS5A, NS5B, and the 3' untranslated region in this

order. This RNA replicon is introduced into a specific cell in an expressible manner so that it can be replicated with actions of regulatory factors such as a promoter.

[0082]

RNA replicon may further comprise a foreign gene and/or an IRES sequence. The foreign gene and the IRES sequence can be preferably positioned between the 5' untranslated region and the sequence coding for NS3 in the order of the foreign gene and the IRES sequence.

[0083]

Preferred examples of the IRES sequence include, but are not limited to, EMCV IRES (internal ribosome entry site of encephalomyocarditis virus), FMDV IRES, HCV IRES, and so forth. EMCV IRES and HCV IRES are more preferred, and EMCV IRES is most preferred.

[0084]

Examples of the foreign gene used include genes showing drug resistance (that is, these genes enable cell selection; cells having this gene will have resistance to the drug) such as, for example, a gene coding for neomycin, hygromycin, puromycin, zeocin, blasticidin, thymidine kinase, kanamycin, or the like; reporter genes (that is, these genes are marker genes that code for a gene product used as an indicator of gene expression) such as, for example, genes coding for an enzyme that catalyses a luminescent reaction or a color reaction of a reporter gene such as, for example, luciferase, green fluorescence protein (GFP), β -galactosidase, and the like; furthermore, target genes of gene therapy and therapeutic nucleic acids such as, for example, genes coding for various proteins useful for the treatment of diseases requiring treatment in mammals including humans such as, for example, enzymes, cytokines, chemokines, hormones, antibodies, immunoregulatory molecules, tumor suppressing proteins, growth factors, membrane proteins, and vasoactive proteins, therapeutic nucleic acids such as antisense RNA and siRNA, and so forth.

[0085]

Specific examples of the HCV subgenomic RNA replicon include pSGR-JFH1 (middle diagram in Figure 2), I₃₈₉/NS3-3'/wt (lower diagram in Figure 2), and so forth. Such

HCV subgenomic RNA replicons can be prepared by the methods described in, for example, Kato, T. *et al.* Gastroenterology, 125 (2003) p1808-1817, a publication by the inventors of the present invention, International Patent Publication WO2004/104198 (Patent Document 3), and so forth.

[0086]

In the phylogenetic analysis method using nucleotide sequences of an HCV strains, HCV is classified into six types: genotypes 1a, 1b, 2a, 2b, 3a, and 3b. Each of these types is further classified into several subtypes. The full-length nucleotide sequences of the HCV genomes of some genotypes have been determined (Simmonds, P. *et al.*, Hepatology, 10 (1994) p1321-1324; Choo, Q.L *et al.*, Science, 244 (1989) p359-362; Okamoto, H. *et al.*, J. Gen. Virol., 73 (1992) p673-679; Mori, S. *et al.*, Biochem. Biophys. Res. Commun. 183 (1992) p334-342; and International Patent Publication WO2004/104198).

[0087]

Specific examples of the HCV strains of genotype 1a include the H77c strain (consensus sequence of the H77 strain: GenBank accession number AF011751), the 1 strain (GenBank accession number M62321), H strain (GenBank accession number M67463), the HC-J1 strain (GenBank accession number D10749), and so forth. Specific examples of the HCV strains of genotype 1b include the J1 strain (GenBank accession number D89815), the con1 strain (GenBank accession number AJ238799, may be referred to as the Con-1 strain), the TH strain (Wakita, T. *et al.*, J. Biol. Chem., 269 (1994) p14205-14210), the J strain (GenBank accession number D90208), the JT strain (GenBank accession number D01171), the BK strain (GenBank accession number M58335), and so forth. Specific examples of the HCV strains of genotype 2a include the JFH1 strain (GenBank accession number AB047639, may be referred to as the JFH-1 strain), the HC-J6 strain (GenBank accession number D00944), the JCH1 strain (GenBank accession number AB047640), the J6CF strain (GenBank accession number AF177036), and so forth. Specific examples of the HCV strains of genotype 2b include the HC-J8 strain (GenBank accession number D01221) and so forth. Specific examples of the HCV strains of genotype 3a include the NZL1 strain (GenBank accession number D17763), the K3a/650 strain (GenBank accession number D28917), the 452

strain (GenBank accession number DQ437509), the E-b1 strain (Chan, S. *et al.*, J. Gen. Virol., 73 (1992) p1131-1141), and so forth. Specific examples of the HCV strains of genotype 3b include the Tr strain (Chayama, K. *et al.*, J. Gen. Virol., 75 (1994) p3623-3628) and so forth. Furthermore, a list of GenBank accession numbers for other strains has also already been reported (Tokita, T. *et al.*, J. Gen. Virol. 79 (1998) p1847-1857; Cristina J. & Colina R. Virology Journal, 3 (2006) p1-8).

[0088]

The elements constituting the HCV subgenomic RNA replicon used in the present invention (specifically, 5' untranslated region, NS3, NS4A, NS4B, NS5A, NS5B, and 3' untranslated region) may be derived from any strain of the above-mentioned genotypes or subtypes thereof so long as the HCV subgenomic RNA replicon can be constructed so that it can be replicated in a cell. It is noted that the present invention is a method for producing a recombinant hepatitis C virus-like particle that has an infecting property but not a transmitting property, and it is preferable that the RNA replicon of the present invention does not include genes coding for the structural proteins of HCV (Core, E1, E2, and p7) to eliminate the transmitting property of the produced virus-like particle.

[0089]

The above-mentioned elements may be derived from the same HCV strain or may be in the combined form (that is, chimera) derived from two or more different HCV strains. Preferred HCV strains include at least one strain selected from the group consisting of HCV strains of genotypes 1b and 2a, and the con1 strain, an HCV strain of genotype 1b, and the JFHI strain, an HCV strain of genotype 2a, are more preferred. The HCV strain in the present invention may be an isolated strain resulting from natural or artificial mutation in the con1 strain or the JFHI strain as a parent strain whose at least genotype is changed from that of the parent strain (derivative). At this time, the phenotypic trait may be the same as or different from that of the parent strain, but a strain having the same trait is preferred.

[0090]

Examples of the HCV subgenomic RNA replicon include an HCV subgenomic RNA replicon having the 5' untranslated region, the sequence coding for the NS3, NS4A,

NS4B, and NS5A proteins derived from HCV strain genomes other than the JFH1 strain (genotype 2a), the sequence coding for the NS5B protein of the JFH1 strain, and the 3' untranslated region; an HCV subgenomic RNA replicon having the 5' untranslated region, the sequence coding for the NS3, NS4A, NS4B, NS5A, and NS5B proteins, and the 3' untranslated region of the JFH1 strain; an HCV subgenomic RNA replicon having the 5' untranslated region, the sequence coding for NS3, NS4A, NS4B, NS5A, and NS5B proteins, and the 3' untranslated region of the HCV-con1 strain (genotype 1b, GenBank accession number AJ238799, Lohmann, V. *et al.*, Science 285 (1999) p110-113), and so forth. Furthermore, a desired foreign gene and an IRES sequence may be included between the 5' untranslated region and the sequence coding for the NS3 protein of these HCV subgenomic RNA replicons.

[0091]

The 5' untranslated region, the sequence of structural proteins (Core, E1, E2, and p7), nonstructural proteins (NS2, NS3, NS4A, NS4B, NS5A, and NS5B), 3' untranslated region, and other sites on the HCV genomic RNA can be defined by using the full-length genomic cDNA sequence, for example, corresponding to the genomic RNA of the JFH1 strain, an HCV strain of genotype 2a (JP Patent Publication (Kokai) No. 2002-171978 A) (GenBank accession number AB047639, Kato, T. *et al.*, Gastroenterology, 125 (2003) p1808-1817, SEQ ID NO: 10. The encoded amino acid sequence is also shown in SEQ ID NO: 11) as reference.

[0092]

For example, in the full-length genome cDNA derived from the JFH1 strain, the 5' untranslated region that can be used as an element of the HCV subgenomic RNA replicon of the present invention is shown by nucleotide positions 1 to 340 of the nucleotide sequence of SEQ ID NO: 10, the region coding for from the Core protein to the p7 protein (Core, E1, E2, and p7) is shown by nucleotide positions 341 to 2779, and the region coding for from the NS3 protein to the 3' untranslated region (NS3, NS4A, NS4B, NS5A, NS5B, and 3'UTR) is shown by nucleotide numbers 3431 to 9678. Regions within genomic cDNA derived from other HCV strains can be identified by comparison with the sequences of these regions derived from the JFH1 strain.

[0093]

An HCV subgenomic RNA replicon can be synthesized with a DNA-dependent RNA polymerase using a vector in which DNA complementary to the HCV subgenomic RNA is cloned into the downstream of a promoter for transcription of RNA from the DNA sequence. Examples of the promoter for transcription of RNA from a DNA sequence include T7, T3, SP6, and so forth, and the T7 promoter is preferred. An HCV subgenomic RNA can be synthesized by T7 polymerase. A cell in which an HCV subgenomic RNA replicon autonomously replicates can be prepared by introducing the thus synthesized HCV subgenomic RNA into a cell that allows propagation of HCV.

[0094]

Preferred examples of the cell include animal cells such as, for example, vertebrate cells including cells of fish, reptiles, amphibians, birds, and mammals, and mammalian cells are most preferred. Further examples of the cell include normal cells derived from the liver, the uterine cervix, and the fetal kidneys, tumor cells, established cell lines thereof, and so forth. Examples thereof include cells such as Huh7, HepG2, IMY-N9, HeLa, and HEK293 (Date, T. *et al.*, J. Biol. Chem., 279 (2004) p22371-22376, , Ito, T. *et al.*, Hepatology 34 (2001) p566-572), and Huh7, HepG2, and clones derived from these cells are preferred.

[0095]

Examples of other methods for replicating the HCV subgenomic RNA in cultured cells include systems utilizing HCV cDNA without using an RNA replicon. When HCV cDNA is expressed using RNA polymerase II-type promoter, the CAP structure is added to the 5' end of the transcribed RNA, and the polyA chain is added to the 3' end. Therefore, the transcribed RNA is used as a template for protein synthesis on the ribosome and the replication of HCV genomic RNA does not occur. To solve this problem, Heller *et al.* prepared a DNA vector by ligating a ribozyme sequence to the 5' and 3' ends of the HCV genome and allowing the ribozyme to cleave the DNA transcribed by RNA polymerase II in a cell, so that HCV RNA to which CAP or polyA is not added can be synthesized in the cell (Heller T *et al.* Proc. Natl. Acad. Sci. USA., 102 (2005) p2579-2583). A cell in which an

HCV subgenomic RNA replicon replicates can be obtained by introducing this vector into a cell.

[0096]

According to another method, a cell in which an HCV subgenomic RNA replicon replicates can be obtained by cloning DNA complementary to the HCV subgenomic RNA into a vector having an RNA polymerase I promoter/terminator system and introducing the vector into a cell that allows propagation of HCV. More specifically, pHH21 (Neumann G. *et al.*, Proc. Natl. Acad. Sci. USA, 96 (1999) p9345-9350) can be used. pHH21 is a vector comprising the human RNA polymerase I promoter as a promoter and the mouse RNA polymerase I terminator as a terminator. When the recognition sequence of the restriction enzyme *BsmBI* is added to the 5' and 3' ends of cDNA complementary to an HCV subgenomic replicon RNA by PCR, the cDNA is digested with *BsmBI*, the HCV genome is inserted into the *BsmBI* site of pHH21, and the HCV genome can be ligated without extra nucleotide sequences between the promoter/terminator and the HCV genome.

[0097]

An HCV subgenomic RNA replicon or a vector such as a vector expressing the HCV subgenomic RNA replicon can be introduced into a cell using any techniques known to those skilled in the art. Examples of such introduction techniques include electroporation, particle gun, lipofection, calcium phosphate method, microinjection, DEAE dextran method, and so forth.

[0098]

In the present invention, a cell in which the HCV subgenomic RNA replicon of the present invention replicates can be prepared according to the above descriptions. Since such an RNA replicon autonomously replicates continuously in the cell, a certain amount thereof is maintained even in a cell subject to RNA degradation. Therefore, the RNA replicon can be maintained in a cell into which the HCV subgenomic RNA replicon of the present invention, a vector expressing the HCV subgenomic RNA replicon, or the like is introduced as described above. In the present invention, "cell carrying an RNA replicon" means that the RNA

replicon exists in the cell not transiently but continuously in a significant amount due to an autonomously replicating ability thereof.

[0099]

According to the method of the present invention, a virus-like particle in which an HCV subgenomic RNA replicon is packaged can be produced by introducing a vector expressing the HCV structural proteins described below into a cell carrying the HCV subgenomic RNA replicon of the present invention.

[0100]

3. Construction of HCV structural protein expressing vector

In the method of the present invention, it is preferable to express the HCV structural protein genes in a cell carrying an HCV subgenomic RNA replicon to supply the HCV structural proteins.

[0101]

The HCV structural proteins consist of Core, E1, E2, and p7. The genes coding for these proteins to supply the HCV structural protein are not limited by HCV genotypes, and each of the genes may be derived from the same HCV strain or may be in the combined form (chimera) derived from two or more different HCV strains. It is sufficient that the HCV structural protein genes are derived from at least one virus strain selected from HCV strains of genotypes 1a, 1b, 2a, 2b, 3a, and 3b. Preferred HCV strains are at least one virus strain selected from the group consisting of 1a, 2a, 3a, and 3b, and more preferred HCV strains are at least one virus strain selected from the group consisting of HCV strains of genotype 1b and 2a. More preferred virus strains include those of at least one type selected from the group consisting of strains of genotype 1a such as H77c, 1, H, and HC-J1, strains of genotype 1b such as J1, con1, TH, J, JT, and BK, and strains of genotype 2a such as JFH1, HC-J6, JCH1, and J6CF. The H77 strain of genotype 1a, the J1 strain of genotype 1b, and the JFH1 strain of genotype 2a are more preferred. The JFH1 strain is most preferred (GenBank accession number AB047639, Kato, T. *et al.*, Gastroenterology, 125 (2003) p1808-1817).

[0102]

The method for expressing these proteins may be any method so long as it is a method by which they can be expressed in a cell, preferably an animal cell, more preferably a mammalian cell. A method using an expression vector into which the above-mentioned genes are incorporated is preferred.

[0103]

In the preferred method of the present invention, a vector expressing the HCV structural proteins (preferably, an expression vector including the HCV structural protein genes in a manner expressible under control of a promoter) is introduced into a cell carrying the HCV subgenomic RNA replicon described in the above section 2 and expressed to supply the HCV structural proteins.

[0104]

Examples of the expression vector include CDM8, pEF1/Myc-His1,2,3, pEF4/Myc-His1,2,3, pcDNA3.1, pREP4, pCEP (all available from Invitrogen Corporation), pCl-neo (Promega Corporation), and so forth. pcDNA5/TO (Invitrogen Corporation), which includes a promoter whose expression can be regulated by tetracycline, can also be used. The promoter is not limited so long as it can express the genes in an animal cell, and examples thereof include the immediate early (IE) promoter of cytomegalovirus, early or late promoter of SV40, metallothionein promoter, retrovirus promoter, heat shock promoter, SR α promoter, elongation factor 1 α promoter, albumin promoter, and so forth.

[0105]

Furthermore, examples of available vectors include viral vectors. The viral vectors are not limited so long as they can infect an animal cell and express a desired foreign gene, and preferred examples thereof include retrovirus vector, adenovirus vector, *Sindbis* virus vector, and vaccinia virus vector. In particular, vaccinia virus vector is preferred since the vaccinia virus vector can express a large amount of gene product (Elroy-Stein, O., *et al.*, Proc. Natl. Acad. Sci. USA, 86 (1989) p6126-6130).

[0106]

It is preferable that the HCV structural protein expressing vector used in the method of the present invention include the Core protein gene, E1 protein gene, E2 protein gene, and

p7 protein gene as the HCV structural protein genes in a manner in which they can be expressed in the host cell. Examples of such an HCV structural protein expressing vector of the present invention include vectors including the Core protein gene, E1 protein gene, E2 protein gene, and p7 protein gene under control of a promoter that can express the inserted genes. In the present invention, the elongation factor 1 α promoter carrying vector, into which the Core protein gene, E1 protein gene, E2 protein gene, and p7 protein gene are inserted under control of the elongation factor 1 α (EF-1 α) promoter, can be used as a particularly preferred HCV structural protein expressing vector. Here, the expression “elongation factor 1 α promoter carrying vector” means a vector including the promoter sequence of the elongation factor 1 α gene (EF-1 α promoter: Mizushima *et al.*, Nucleic Acids Res., 18 (1990) p5322) located in a manner in which genes under control thereof can be expressed in the host cell. Examples thereof include pEF1/Myc-His1,2,3 and pEF4/Myc-His1,2,3 (both available from Invitrogen Corporation).

[0107]

Another preferred example of the HCV structural protein expressing vector of the present invention is a vaccinia virus vector comprising the Core protein gene, E1 protein gene, E2 protein gene, and p7 protein gene in an expressible manner (recombinant vaccinia virus vector). Vaccinia virus strains such as, for example, the DIs, WR, and IBTd strains (Meis, RJ & Condit, RC. Virol. 182 (1992) p442-454) can be preferably used for preparation of a recombinant vaccinia virus vector. The method for preparing a recombinant vaccinia virus vector is also described in detail in the examples described later. In brief, a desired recombinant vaccinia virus vector can be produced by cloning the above-mentioned HCV structural protein genes under control of a vaccinia virus promoter such as p.7.5 in a vaccinia virus transfer vector, further introducing the transfer vector into a cell infected by vaccinia virus by electroporation or the like, culturing the cell to produce viral particles, and further preferably selecting the virus and purifying it. Such a vaccinia virus vector can be prepared in the form of a recombinant virus-like particle.

[0108]

Since the HCV structural proteins (Core, E1, E2, p7) and the nonstructural proteins (NS3, NS4A, NS4B, NS5A, and NS5B) are translated from the translated region as one polyprotein, subjected to limited digestion with protease, released, and produced, it is preferable to express these HCV structural proteins as a polyprotein of Core, E1, E2, and p7 in a continuous stretch, but these proteins may be expressed by separate expression vectors.

[0109]

Whether the structural proteins are expressed in a cell into which a structural protein expressing vector is introduced can be detected by reacting a cell culture solution or proteins extracted from cells with antibodies against the structural proteins (WO2004/104198).

[0110]

Specifically, for example, a protein sample extracted from cells is fractionated by SDS-polyacrylamide gel electrophoresis, blotted on a nitrocellulose membrane, and reacted with an anti-HCV protein antibody (e.g., anti-Core specific antibody or antiserum collected from a patient with hepatitis C), and the antibody can be detected (by western blotting).

[0111]

Alternatively, cells expressing the HCV proteins are immunostained using a similar antibody, and expression and intracellular localization of these proteins can be confirmed.

[0112]

4. Packaging of HCV subgenomic RNA replicon into particle

In the method of the present invention, a virus-like particle in which an HCV subgenomic RNA replicon is packaged by the structural proteins is produced in a cell by supplying a vector expressing the HCV structural proteins into a cell carrying the HCV subgenomic RNA replicon.

[0113]

To package in a viral particle an HCV subgenomic RNA replicon in a cell in which the HCV subgenomic RNA replicon replicates, a vector expressing the structural proteins (Core, E1, E2, and p7) can be introduced into the cell and expressed. Alternatively, the HCV subgenomic RNA can be introduced into a cell in which the structural proteins (Core, E1, E2, and p7) are stably expressed.

[0114]

Examples of such an introduction method include known methods such as electroporation, particle gun, lipofection, calcium phosphate method, microinjection, and DEAE dextran method.

[0115]

5. Production of recombinant HCV virus-like particle

The cell carrying an HCV subgenomic RNA replicon prepared as described above into which the HCV structural protein (Core, E1, E2, and p7) genes are introduced and expressed (recombinant HCV-like particle producing cell) can produce a recombinant virus-like particle. The produced recombinant HCV-like particle has an infecting ability and an ability of replicating the HCV subgenomic RNA. However, it does not have a transmitting property (transmitting ability), since the infected cell cannot produce a daughter viral particle.

[0116]

Therefore, a recombinant HCV-like particle can be prepared in a cell culture system by culturing the recombinant HCV particle producing cell of the present invention. The HCV-like particle can be obtained preferably by culturing recombinant HCV-like particle producing cells and recovering a virus-like particle produced in the culture (preferably a culture solution). A virus-like particle can be recovered from the above-mentioned culture solution by techniques such as, for example, sucrose density gradient centrifugation.

[0117]

The viral particle producing ability of the recombinant HCV-like particle producing cell of the present invention can be confirmed by any virus detection methods known to those skilled in the art. For example, the viral particle producing ability can be determined by fractionating a culture solution of cells that appear to produce a virus-like particle by a sucrose density gradient and measuring the density of each fraction and the concentration of the HCV Core protein or the HCV replicon RNA in the fraction to see whether specific gravity matches the known specific gravity of HCV. Furthermore, when the density of a fraction in which a peak of the Core protein is detected is lower than the density of the fraction obtained by

fractionating the culture solution after treated with 0.25% NP40 (polyoxyethylene(9) octylphenyl ether), it can be determined that the cell has a virus-like particle producing ability.

[0118]

Furthermore, whether a virus-like particle in a recombinant HCV-like particle producing cell has an infecting ability can be determined by detecting the phenotype of a foreign gene that exists in an HCV subgenomic RNA packaged in the viral particle. For example, if the foreign gene is a drug resistance gene, it can be assessed by inoculating the viral particle in an HCV-permissive cell, culturing usually for 2 to 3 weeks in the presence of this drug, and counting drug-resistant clones.

[0119]

Furthermore, it can be confirmed that a virus-like particle in a recombinant HCV-like particle producing cell does not produce a daughter viral particle in an infected cell, by western blotting described above or the like whether the HCV structural proteins exist in an extract from the infected cell, preferably an infected cell culture supernatant sample.

[0120]

A recombinant HCV-like viral particle produced by the method of the present invention has an ability of infecting a cell (preferably HCV-permissive cell). There is also provided a method for producing a recombinant hepatitis C virus infected cell comprising the steps of culturing a recombinant HCV-like particle producing cell and allowing a virus-like particle in the obtained culture (preferably culture broth) to infect another cell (preferably HCV-permissive cell). Here, the HCV-permissive cell is a cell having an ability of replicating HCV genomic RNA and/or being infected by HCV and is not limited to these examples. Specific examples of hepatic cells include primary hepatocyte, Huh7 cell, HepG2 cell, IMY-N9 cell, HeLa cell, and so forth. Specific examples of lymphoid cells include the Molt4 cell, HPB-Ma cell, Daudi cell, and so forth. However, hepatic and lymphoid cells are not limited to these examples.

[0121]

For easier understanding, the production processes of the recombinant HCV-like particle explained in the above sections 2 to 5 are schematically shown in Figure 1.

[0122]

6. Vector for gene introduction

The recombinant HCV-like particle of the present invention produced by the method of the present invention is characterized by having on the RNA genome a nucleotide sequence comprising the 5' untranslated region, the nucleotide sequence coding for the NS3, NS4A, NS4B, NS5A, and NS5B proteins, and the 3' untranslated region, derived from the above-mentioned HCV strains (at least one virus strain selected from genotypes 1a, 1b, 2a, 2b, 3a, and 3b, preferably 1b and 2a such as, for example, the con1 strain of genotype 1b and the JFH1 strain of genotype 2a).

[0123]

In addition, the recombinant HCV-like particle of the present invention has an interesting characteristic that, when the HCV-like particle produced in a recombinant HCV-like particle producing cell by the method of the present invention is allowed to infect a cell (e.g., an HCV-permissive cell described above as an example), the above-mentioned HCV subgenomic RNA is replicated in the infected cell, but a daughter viral particle is not formed.

[0124]

The recombinant HCV-like particle of the present invention can be used as a vector for gene introduction/expression by inserting a desired foreign gene into an HCV subgenomic RNA replicon packaged therein. Such a recombinant HCV-like viral particle of the present invention comprising a foreign gene can be prepared by preparing an HCV subgenomic RNA replicon in which the foreign gene is inserted between the 5' untranslated region and the IRES sequence and packaging it by the above-mentioned method of the present invention. Since the HCV particle produced in the recombinant HCV particle producing cell does not have a transmitting ability, it can also be used as a vector for gene introduction targeting hepatic or lymphoid cells or tissues.

[0125]

Since an HCV subgenomic RNA packaged in a viral particle by the viral particle production method of the present invention is not incorporated into the chromosomal genome in an HCV-permissive cell infected by the virus-like particle of the present invention, it has an

55232-7

advantage that normal genes are not damaged or genes in the vicinity of the insertion site are not activated by the gene insertion.

[0126]

Due to the above-mentioned characteristics, the vector of the present invention can be used for, for example, gene therapy or construction of transgenic animals by introducing a foreign gene.

[0127]

Examples of the foreign gene (or foreign nucleic acid) to be introduced into an HCV subgenomic RNA replicon and packaged in a viral particle include, but not limited to, genes coding for proteins derived from mammals including humans, for example, various proteins involved in diseases such as proteins, polypeptides, or peptides including, for example, enzymes, cytokines, chemokines, hormones, antibodies, immunoregulatory molecules, tumor suppressing proteins, growth factors, membrane proteins, and vasoactive proteins; therapeutic nucleic acids such as antisense RNA and siRNA that inhibit or suppress translation of proteins, and so forth.

[0128]

Target HCV-susceptible cells or tissues are mammal cells or tissues, preferably human cells or tissues such as, for example, human hepatic and lymphoid cells or tissues. The vector of the present invention is allowed to act on target cells or tissues under *in vivo*, *in vitro*, or *ex vivo* conditions. Preferably, the vector of the present invention can be used for treatment of humans, for example, gene therapy, treatment of cancer (e.g., liver cancer, lymphoma, etc.), and the like.

[0129]

The contents of the specification and/or the drawings of JP Application No. 2005-287825, to which the present application claims the priority, are encompassed in the present specification.

25 [0130]

Examples

[0131]

The present invention will be explained more specifically with reference to the following examples. However, these examples are only for illustration, and the scope of the present invention is not limited to these examples.

[0132]

Example 1

Preparation of replicon carrying cell

Plasmid DNA pSGR-JFH1 (middle diagram of Figure 2) was constructed by replacing part of the structural regions and the nonstructural regions with the neomycin resistance gene (neo: also referred to as neomycin phosphotransferase gene) and EMCV-IRES (internal ribosome entry site of encephalomyocarditis virus) in pJFH1 which has been prepared by inserting DNA containing the full-length genome cDNA of the JFH-1 strain (genotype 2a), a hepatitis C virus strain isolated from a patient with fulminant hepatitis (JFH-1 clone: GenBank accession number AB047639) into the downstream of T7 promoter in the pUC19 plasmid. This construction procedure was performed according to a previous report (Lohmann *et al.*, Science, 285 (1999) p110-113).

[0133]

Specifically, plasmid pJFH1 was digested with restriction enzymes *Age*I and *Cla*I, and a sequence from pJFH1-derived 5'NTR to the Core region and the pRSV5NEO-derived neomycin resistance gene were ligated to the cleavage sites by PCR amplification, a fragment digested with the restriction enzymes *Age*I and *Pme*I and a sequence from EMCV IRES to the NS3 region were ligated by PCR amplification, and a fragment digested with restriction enzymes *Pme*I and *Cla*I was inserted and ligated.

[0134]

Subsequently, pSGR-JFH1 was digested with restriction enzyme *Xba*I. Then, 10 to 20 μ g of these *Xba*I-digested fragments were further treated by incubation using 20 units of Mung Bean Nuclease (total volume of reaction mixture, 50 μ l) at 30°C for 30 minutes.

Mung Bean Nuclease is an enzyme that catalyzes a reaction of selectively degrading a single-stranded portion in a double-stranded DNA. Usually, when RNA is synthesized using the above-mentioned *Xba*I-digested fragment as it is as a template, a replicon RNA is synthesized with extra four nucleotides of CTGA, which is a part of the recognition sequence of *Xba*I, added to the 3' end. Accordingly, in this example, by treating the *Xba*I-digested fragment with Mung Bean Nuclease, four nucleotides of CTGA were removed from the *Xba*I-digested fragment. Subsequently, to obtain a template DNA, a solution containing the *Xba*I-digested fragment treated with Mung Bean Nuclease was subjected to protein removal treatment according to a conventional method to purify the *Xba*I-digested fragment from which the four nucleotides of CTGA were removed.

[0135]

Subsequently, RNA was synthesized *in vitro* by T7 RNA polymerase using this template DNA. For this RNA synthesis, the MEGAscript from Ambion was used. 20 µl of the reaction mixture containing 0.5 to 1.0 µg of template DNA was reacted according to the manufacturer's instructions.

[0136]

After completion of RNA synthesis, DNase (2 units) was added to the reaction solution and reacted at 37°C for 15 minutes, and then RNA extraction was further performed with acidic phenol to remove the template DNA.

[0137]

0.01 ng to 10 µg of this RNA (replicon RNA) was mixed with total cellular RNA extracted from the Huh7 cell and adjusted so that the total RNA amount should be 10 µg. Then, the mixed RNA was introduced into the Huh7 cell by electroporation. The electroporated Huh7 cells were seeded on a culture dish and cultured for 16 to 24 hours, and then G418 (neomycin) was added to the culture dish at various concentrations. Then, the culture was continued while replacing the culture medium twice weekly. Colonies of viable cells were cloned from the culture dish after 21 days of the above-mentioned culture, and the culture was continued. Some strains of cell clones could be established by cloning such

colonies. One cell strain carrying the HCV subgenomic RNA replicon was designated as 1H4.1.

[0138]

Furthermore, the 5-15 cell, a cell strain carrying an HCV subgenomic RNA replicon (GenBank accession number, AJ242654; I₃₈₉/NS3-3'/wt in the lower column of Figure 2) prepared from cDNA of the full-length genome derived from the Con-1 strain of HCV genotype 1b in the same manner as described above, that was prepared by introducing this RNA replicon into the Huh7 cell strain (Lohmann *et al.*, Science, 285 (1999) p110-113), was also used for experiments.

[0139]

Example 2

Preparation of structural protein expressing vector

1) Structural protein expressing plasmid vector

A region including the structural region genes (nucleotide positions: 249 to 2781) of the JFH1 strain isolated from a patient with fulminant hepatitis (GenBank accession number AB047639) (Kato T. *et al.*, J. Med. Virol. 64 (2001) p334-339) was amplified by PCR. This DNA fragment was digested with *NheI* and *EcoRI* and thus an obtained fragment containing the structural genes was purified by agarose gel electrophoresis and blunt-ended by DNA polymerase. This blunt-ended cDNA was inserted into the downstream of the CAG promoter sequence (CAG) in a plasmid vector. Similarly, the above-mentioned cDNA containing the structural region genes obtained by digesting with *NheI* and *EcoRI* was inserted between the *SpeI* and *EcoRI* recognition sites in pEF4/Myc-His (Invitrogen Corporation), a vector carrying the elongation factor 1 α gene promoter sequence (EF-1 α promoter: Mizushima *et al.*, Nucleic Acids Res., 18 (1990) p5322). The resulting obtained plasmids were designated as pCAGC-p7JFH1 and pEF4C-p7JFH1, respectively (Figure 3).

[0140]

2) Recombinant vaccinia virus vector expressing structural proteins

To prepare a vector that contains the structural genes of the JFH1 strain and can express the proteins encoded by these genes, first, pEF4C-p7JFH1 shown in the upper diagram

of Figure 3 was digested with restriction enzymes *Bam*HI and *Eco*RI, and the region coding for the Core, E1, E2, and p7 proteins was fractionated by agarose gel electrophoresis. Subsequently, this fragment was ligated to a vaccinia virus transfer vector pDIsgptmH5 which is designed so that the xanthine-guanine phosphoribosyl transferase (XGPRT) gene should be inserted together with a foreign gene of interest (Ohnishi, K. *et al.*, Jap. J. Infect. Dis. 58 (2005) p88-94; Ishii, K. *et al.*, Virology 302 (2002) p433-444). This pDIsgptmH5 is a transfer vector into which the XGPRT gene of *Escherichia coli* is incorporated under control of the vaccinia virus p7.5 promoter inserted into a cloning site of the pUc/DIs vector (Ishii, K. *et al.*, Virology 302 (2002) p433-444). The obtained vector was designated as pDIsJFHst.

[0141]

A vector that comprises the structural genes of the H77c strain and can express the proteins encoded by these genes was prepared by the following method. First, a vector into which the HCV genomic cDNA of the H77c strain (GenBank accession number AF011751) was cloned as a template, 5 µl of 10x buffer accompanied by LA-PCR Kit (Takara Bio Inc.), 5 µl of 2.5 mM dNTP mixture, and 1 µl each of 10 µM H77/J1 forward primer (AAAGATCTGCGAAAGGCCTTGTGGTACTGC: SEQ ID NO: 1) and H77 reverse primer (AAGAGCTCTCATAACCCGACAAGAACAACGCCGCC: SEQ ID NO: 2) were added, and deionized water was finally added to make 49 µl as a total volume. Then, 1 µl of Takara LA Taq (Takara Bio Inc.) was added, and PCR reaction was performed. The PCR reaction was performed under the following condition: 25 cycles of 98°C for 20 seconds and 68°C for 5 minutes (per one cycle). When a part of the PCR products were subjected to electrophoresis on an agarose gel, about 2.5-kb amplification product was confirmed.

[0142]

Accordingly, a ligation reaction was performed using 2 µl of the PCR products to ligate an amplification product into a plasmid vector. *Escherichia coli* was transformed with this ligation product according to a conventional method, and plasmid DNA was prepared using the obtained transformant. This plasmid DNA was digested with restriction enzymes that can remove the DNA fragment inserted into the plasmid DNA and subjected to agarose gel electrophoresis to confirm that about 2.5-kb DNA fragment was inserted into the plasmid

DNA. The nucleotide sequence of the inserted DNA fragment was determined by a conventional method. As a result, the determined nucleotide sequence was found to match the sequence of nucleotide positions 271 to 2819 in the nucleotide sequence with GenBank accession number AF011751. Subsequently, this plasmid DNA was digested with *Bgl*II and *Sac*I and subjected to agarose electrophoresis to isolate a DNA fragment containing the structural gene region of the H77c strain, which was ligated to the vaccinia virus transfer vector pDisgptmH5 (Ohnishi, K. *et al.*, Jap. J. Infect. Dis. 58 (2005) p88-94; Ishii, K. *et al.*, Virology 302 (2002) p433-444). The vector obtained as a result was designated as pDisH77st.

[0143]

A vector that comprises the structural genes of the J1 strain and can express the proteins encoded by these genes was prepared by the following method. First, a vector into which the HCV genomic cDNA of the J1 strain (GenBank accession number D89815) was cloned as a template, 5 µl of 10x buffer accompanied by LA-PCR Kit (Takara Bio Inc.), 5 µl of 2.5 mM dNTP mixture, and 1 µl each of 10 µM H77/J1 forward primer (AAAGATCTGCGAAAGGCCTTGTGGTACTGC: SEQ ID NO: 1) and J1 reverse primer (AAGAGCTCTCATAGACCTACAAAAACCCCGCCTCC: SEQ ID NO: 3) were added, and deionized water was finally added to make 49 µl as a total volume. Then, 1 µl of Takara LA Taq (Takara Bio Inc.) was added, and PCR reaction was performed. The PCR reaction was performed under the following condition: 25 cycles of 98°C for 20 seconds and 68°C for 5 minutes (per one cycle). When a part of the PCR products were subjected to electrophoresis on an agarose gel, about 2.5-kb amplification product was confirmed. Accordingly, a ligation reaction was performed using 2 µl of the PCR products to ligate an amplification product into the plasmid vector. *Escherichia coli* was transformed with this ligation product according to a conventional method, and plasmid DNA was prepared using the obtained transformant. This plasmid DNA was digested with restriction enzymes that can remove the DNA fragment inserted into the plasmid DNA and subjected to agarose gel electrophoresis to confirm that about 2.5-kb DNA fragment was inserted into the plasmid DNA. The nucleotide sequence of the inserted DNA fragment was determined by a conventional method.

As a result, the determined nucleotide sequence was found to match the sequence of nucleotide positions 271 to 2819 in the nucleotide sequence with GenBank accession number D89815. Subsequently, this plasmid DNA was digested with *Bgl*II and *Sac*I and subjected to agarose electrophoresis to isolate a DNA fragment containing the structural gene region of the J1 strain, which was ligated to the vaccinia virus transfer vector pDisgptmH5 (Ohnishi, K. *et al.*, Jap. J. Infect. Dis. 58 (2005) p88-94; Ishii, K. *et al.*, Virology 302 (2002) p433-444). The resulting obtained vector was designated as pDisJ1st.

[0144]

A vector that comprises a chimeric structural gene sequence of the Core gene derived from the J1 strain and the E1, E2, and p7 genes derived from the JFH1 strain and can express the proteins encoded by these genes was prepared by the following method. First, to amplify the Core gene of the J1 strain, a vector into which the HCV genomic cDNA of the J1 strain (GenBank accession number D89815) was cloned as a template, 5 µl of 10x buffer accompanied by LA-PCR Kit (Takara Bio Inc.), 5 µl of 2.5 mM dNTP mixture, and 1 µl each of 10 µM H77/J1 forward primer (SEQ ID NO: 1) and J1/JFH1 reverse primer (GTAGCTGCTACTGGTATTCTTCACCTGGGCAGCGGAAGCTGGGATGGTCAAACAG GACAG: SEQ ID NO: 4) were added, and deionized water was finally added to make 49 µl as a total volume. Then, 1 µl of Takara LA Taq (Takara Bio Inc.) was added, and PCR reaction was performed. The PCR reaction was performed under the following condition: 25 cycles of 98°C for 20 seconds and 68°C for 5 minutes (per one cycle). To amplify the E1, E2, and p7 genes of the JFH1 strain, a vector into which the HCV genomic cDNA of the JFH1 strain (GenBank accession number AB047639) was cloned as a template, 5 µl of 10x buffer accompanied by LA-PCR Kit (Takara Bio Inc.), 5 µl of 2.5 mM dNTP mixture, and 1 µl each of 10 µM J1/JFH1 forward primer (CTGTCCTGTTTGACCATCCCAGCTTCCGCTGCCCAGGTGAAGAATACCAGTAGCA GCTAC: SEQ ID NO: 5) and JFH1 reverse primer (AAGAGCTCTCAATCAATATCAACAAACCCACGCCT: SEQ ID NO: 6) were added, and deionized water was finally added to make 49 µl as a total volume. Then, 1 µl of Takara LA Taq (Takara Bio Inc.) was added, and PCR reaction was performed. The PCR reaction was

performed under the following condition: 25 cycles of 98°C for 20 seconds and at 68°C for 5 minutes (per one cycle). The obtained amplified fragments were purified and dissolved in 50 µl of H₂O. 1 µl of each solution was diluted 100-fold, and 1 µl of each solution was combined into one mixture. Using this mixture as a template, 5 cycles of LA-PCR were performed under the above-mentioned conditions without adding primers. Then, H77/J1 forward primer (SEQ ID NO: 1) and JFH1 reverse primer (SEQ ID NO: 6) were added, 10 cycles of LA-PCR were further performed, and the amplified chimeric DNA fragment was purified. This fragment was cloned into the plasmid vector, and the nucleotide sequence of the DNA fragment was determined. As a result, it was confirmed that the DNA fragment has a chimeric structural gene sequence of the Core gene derived from the J1 strain and the E1, E2, and p7 genes derived from the JFH1 strain. Subsequently, a fragment obtained by digesting this plasmid with *Bgl*III and *Sac*I was ligated to the vaccinia virus transfer vector pDIsgptmH5 (Ohnishi, K. *et al.*, Jap. J. Infect. Dis. 58 (2005) p88-94; Ishii, K. *et al.*, Virology 302 (2002) p433-444). The resulting obtained vector was designated as pDIJ1(c)/JFH1(E1-p7)st.

[0145]

A vector that comprises a chimeric structural gene sequence of the Core gene derived from the JFH1 strain and the E1, E2, and p7 genes derived from the J1 strain and can express the proteins encoded by these genes was prepared by the following method. First, to amplify the Core gene of the JFH1 strain, a vector into which the HCV genomic cDNA of the JFH1 strain (GenBank accession number AB047639) was cloned as a template, 5 µl of 10x buffer accompanied by LA-PCR Kit (Takara Bio Inc.), 5 µl of 2.5 mM dNTP mixture, and 1 µl each of 10 µM JFH1 forward primer (AAAGATCTGCGAAAGGCCTTGTGGTACTGC: SEQ ID NO: 7) and JFH1/J1 reverse primer (GGTATATCCCGGACACGTTGCGCACTTCATAAGCAGAGACCGGAACGGTGATGC AGGAC: SEQ ID NO: 8) were added, and deionized water was finally added to make 49 µl as a total volume. Then, 1 µl of Takara LA Taq (Takara Bio Inc.) was added, and PCR reaction was performed. The PCR reaction was performed under the following condition: 25 cycles of 98°C for 20 seconds and 68°C for 5 minutes (per one cycle). To amplify the E1, E2, and p7 genes of the J1 strain, a vector into which the HCV genomic cDNA of the J1 strain

(GenBank accession number D89815) was cloned as a template, 5 μ l of 10x buffer accompanied by LA-PCR kit (Takara Bio Inc.), 5 μ l of 2.5 mM dNTP mixture, and 1 μ l each of 10 μ M JFH1/J1 forward primer (GTCCTGCATCACCGTTCCGGTCTCTGCTTATGAAGTGCGCAACGTGTCCGGGATA TACC: SEQ ID NO: 9) and J1 reverse primer (AAGAGCTCTCATAGACCTACAAAAACCCCGCCTCC: SEQ ID NO: 3) were added, and deionized water was finally added to make 49 μ l as a total volume. Then, 1 μ l of Takara LA Taq (Takara Bio Inc.) was added, and PCR reaction was performed. The PCR reaction was performed under the following condition: 25 cycles of 98°C for 20 seconds and 68°C for 5 minutes (per one cycle). The obtained amplified fragments were purified and dissolved in 50 μ l of H₂O. 1 μ l of each solution was diluted 100-fold, and 1 μ l of each solution was combined into one mixture. Using this mixture as a template, 5 cycles of LA-PCR were performed under the above-mentioned conditions without adding primers. Then, JFH1 forward primer (SEQ ID NO: 7) and J1 reverse primer (SEQ ID NO: 3) were added, 10 cycles of LA-PCR were further performed, and the amplified chimeric DNA fragment was purified. This fragment was cloned into the plasmid vector, and the nucleotide sequence of the DNA fragment was determined. As a result, it was confirmed that the DNA fragment has a chimeric structural gene sequence of the Core gene derived from the JFH1 strain and the E1, E2, and p7 genes derived from the J1 strain. Subsequently, a fragment obtained by digesting this plasmid with *Bgl*II and *Sac*I was ligated to the vaccinia virus transfer vector pDIsGptmH5 (Ohnishi, K. *et al.*, Jap. J. Infect. Dis. 58 (2005) p88-94; Ishii, K. *et al.*, Virology 302 (2002) p433-444). The vector obtained as a result was designated as pDIsJFH(c)/J1(E1-p7)st.

[0146]

The maps of the HCV structural gene sequences (chimeric structural gene sequence) inserted into the vectors prepared as described above, pDIsJFHst, pDIsH77st, pDIsJ1st, pDIsJ1(c)/JFH(E1-p7)st, and pDIsJFH(c)/J1(E1-p7)st, are shown in Figure 4.

[0147]

The recombinant vaccinia virus vector DIs strain carrying each of the above-mentioned vectors was prepared and selected as follows, for example.

55232-7

[0148]

500 μ l of virus solution containing about 10^6 plaque forming units (pfu) of the vaccinia virus DIs strain was inoculated on an 80-mm plate on which about 10^7 chick embryo fibroblast (CEF) cells were seeded, and the virus was allowed to infect cells by shaking every 15 minutes 8 times. Then, Dulbecco's Modified Eagle Medium (DMEM) with 1 ml of 10% fetal calf serum (FCS) was added, and the mixture was cultured at 37°C under 5% CO₂ for 2 hours. The medium was removed, cells were washed with phosphate-buffered serine (PBS), and 0.5 ml of 0.05% trypsin solution was added to release the cells. Then, the cell suspension was centrifuged at 2000 rpm for 3 minutes to recover the cells, and the cells were suspended in 400 μ l of PBS. 10 μ g of the above-mentioned transfer vector was dissolved in this cell suspension, and electroporation was performed in a 0.4-cm cuvette using Gene Pulser™ II (Bio-Rad Laboratories, Inc.), with a voltage applied once at 250 v and 500 μ FD. The cells were suspended in 2 ml of DMEM containing 10% FCS, seeded on a 35-mm plate, and cultured at 37°C under 5% CO₂ for 7 days. The infected cells were recovered with the medium, lyophilized 3 times, ultrasonicated for 2 minutes, and then diluted 10-, 100-, or 1000-fold with the same medium. 10^6 cells were seeded on a 35-mm plate, followed by addition of 25 μ g/ml of MPA, 250 μ g/ml of xanthine, and 15 μ g/ml of hypoxanthine to the medium (DMEM containing 10% FCS), and cultured overnight. Then, the above-mentioned diluted cell solutions were inoculated. The virus was allowed to infect cells by shaking every 15 minutes 8 times, the diluted cell solution was removed, then 2 ml of 1% soft-agar added medium (DMEM with 10% FCS; which contains MPA, xanthine, and hypoxanthine) was added, and the mixture was solidified and cultured at 37°C under 5% CO₂ for 7 days. The formed plaque portions were picked up with a Pasteur pipette, suspended in 200 μ l of DMEM containing 10% FCS, and ultrasonicated for 2 minutes to release the virus from agar. This culture solution was diluted 10-, 100-, and 1000-fold with the same medium, the same plaque assay procedure as described above was repeated further twice to purify the recombinant virus, and the processes were scaled up by infecting the CEF cells.

[0149]

Viral vectors (recombinant virus-like particles) prepared as described above from pDIsJFHst, pDIsH77st, pDIsJ1st, pDIsJ1(c)/JFH(E1-p7)st, and pDIsJFH(c)/J1(E1-p7)st were designated as DIsJFHst, DIsH77st, DIsJ1st, DIsJ1(c)/JFH(E1-p7)st, and DIsJFH(c)/J1(E1-p7)st, respectively.

[0150]

Example 3

Introduction of structural protein expressing vector into replicon carrying cell and production of structural protein

To express the HCV structural proteins in a replicon carrying cell, the HCV structural protein expressing vector pCAGC-p7JFH1 or pEF4C-p7JFH1 prepared in Example 2 was introduced into a replicon carrying cell by lipofection and the like. Furthermore, the viral vectors expressing the HCV structural proteins prepared in Example 2, DIsJFHst, DIsH77st, DIsJ1st, DIsJ1(c)/JFH(E1-p7)st, and DIsJFH(c)/J1(E1-p7)st, were allowed to infect replicon carrying cells.

[0151]

1) Introduction of structural protein expressing plasmid vector

pCAGC-p7JFH1 was introduced into the replicon carrying cell 5-15 by lipofection, then the cells were continuously cultured in an 8 ml culture solution, and the culture supernatant was recovered at 4 days to quantify the HCV Core protein. However, the amount was below detection limit.

[0152]

Meanwhile, pEF4C-p7JFH1 was introduced into the replicon carrying cell IH4.1 by lipofection. As a result, the HCV Core protein could be detected in the culture supernatant by western blotting. Accordingly, the replicon carrying cells IH4.1 into which pEF4C-p7JFH1 was introduced were cultured for 4 days, and then a culture medium (8 ml) was collected and centrifuged at 8,000 g and 4°C for 60 minutes to collect the culture supernatant. Subsequently, this supernatant was centrifuged using SW20 Rotor (Beckman) at 25,000 rpm and 4°C for 4 hours, and pellets were suspended in 1 ml of buffer. The sample was overlaid on 10 to 60% sucrose density gradients prepared in a tube for SW41E Rotor (Beckman) and

centrifuged at 35,000 rpm and 4°C rpm for 16 hours. The 10 to 60% sucrose density gradients were prepared by layering 2 ml of 60% (weight/weight) sucrose solution (dissolved in 50 mM Tris, pH 7.5/0.1 M NaCl/1 mM EDTA), 1 ml of 50% sucrose solution, 1 ml of 40% sucrose solution, 1 ml of 30% sucrose solution, 1 ml of 20% sucrose solution, and 1 ml of 10% sucrose solution in a centrifuge tube.

[0153]

After completion of centrifugation, 0.5 ml each of fractions was collected from the bottom of the tube. The density, the HCV Core protein concentration, and the RNA concentration were determined for each fraction. The HCV Core protein was quantified by ortho-HCV antigen IRMA test (Aoyagi *et al.*, J. Clin. Microbiol., 37 (1999) p1802-1808). HCV replicon RNA was quantified according to the method by Takeuchi (Takeuchi *et al.*, Gastroenterology, 116 (1999) p636-642). As shown in Figure 5, the peaks of the replicon RNA and the Core protein matched and were both in fraction 8 in two experiments. The density of this fraction matched the reported density of the HCV particle, with about 1.17 g/ml. This suggested that viral particles were produced.

[0154]

2) Introduction of HCV structural protein expressing recombinant vaccinia virus vector

2×10^6 cells of the replicon carrying cell strain 5-15 were seeded on a 10-cm dish, and 0.5 pfu/cell of DIsJFHst was allowed to infect the replicon carrying cell strain on the following day. The culture was continued in an 8 ml culture medium. After 4 days of culture, the culture solution was recovered and centrifuged at 8,000 g and 4°C for 60 minutes, and the culture supernatant was collected. Then, this supernatant was centrifuged using SW20 Rotor (Beckman) at 25,000 rpm and 4°C for 4 hours, pellets equivalent to 8 ml of the cell culture solution were suspended in 1 ml of buffer with or without 0.2% NP40. The sample was incubated at 4°C for 20 minutes, overlaid on 10 to 60% sucrose density gradients in a tube for SW41E Rotor (Beckman), and centrifuged at 35,000 rpm and 4°C for 16 hours. The 10 to 60% sucrose density gradient were prepared by layering 2 ml of 60% (weight/weight) sucrose solution (dissolved in 50 mM Tris, pH 7.5/0.1 M NaCl/1 mM EDTA),

1 ml of 50% sucrose solution, 1 ml of 40% sucrose solution, 1 ml of 30% sucrose solution, 1 ml of 20% sucrose solution, and 1 ml of 10% sucrose solution in a centrifuge tube.

[0155]

After completion of centrifugation, 0.5 ml each of fractions was recovered from the bottom of the tube. The density and the HCV Core protein concentration were determined for each fraction. The HCV Core protein was quantified by ortho-HCV antigen IRMA test (Aoyagi *et al.*, J. Clin. Microbiol., 37 (1999) p1802-1808).

[0156]

Results of two independent experiments are shown in Figure 6. In the NP40 untreated group (treated with PBS), the density of the particle containing the Core protein was 1.16 g/ml (fraction 7). In the NP40 treated group, the density of the particle containing the Core protein was 1.21 g/ml (fraction 9). This suggested that a surface membrane that had a light specific gravity because of lipids contained was removed from the viral particle by NP40, forming a core particle having the nucleic acid and the Core protein alone without a virus-like structure, and thus the specific gravity increased. This suggested that a complete viral particle was produced in this experimental system.

[0157]

In the same manner as described above, viral vectors DIIsJ1st, DIIsJ1(c)/JFH(E1-p7)st, and DIIsJFH(c)/J1(E1-p7)st were further allowed to infect the replicon carrying cell strain 5-15. 8 ml of supernatant obtained by culturing the cells for 4 days after infection was concentrated with an ultrafiltration membrane and fractionated by the above-mentioned sucrose density gradient centrifugation. The density and the HCV Core protein concentration were determined for each fraction. The density distribution pattern of the HCV Core protein showed that the produced virus-like particle was contained in the culture supernatant of cells infected by DIIsJ1st, DIIsJ1(c)/JFH(E1-p7)st, or DIIsJFH(c)/J1(E1-p7)st.

[0158]

Example 4

Confirmation of infecting ability of recombinant HCV-like particle

55232-7

As shown in Figure 1, the recombinant HCV particle prepared in the above-described examples has the *neo* gene as a drug resistance marker. Therefore, to confirm that the particle obtained in the Example 3 has an infecting ability, it is sufficient to allow this particle to infect the Huh7 cell and examine whether G418 (neomycin) resistance colonies can be obtained.

[0159]

DIJFHst was allowed to infect the replicon carrying cell strain 5-15, the culture supernatant obtained by culturing the cells for 4 days was concentrated 30 times by ultrafiltration membrane (cut off, 1×10^5 Da) to infect the Huh7 cells. After infection, 1 mg/ml G418 was added to the culture dish. Then, the culture was continued while replacing the culture medium twice weekly. After cultured for 21 days after seeding, viable cells were stained with crystal violet. As a result, colony formation was confirmed.

[0160]

If the HCV structural proteins are not detected in an infected cell, it means that daughter particles are not produced in the infected cell. Therefore, colonies formed in this experiment were propagated, and cell extracts thereof were prepared. Then, proteins in these extracts were analyzed by SDS-PAGE and western blotting. In the analyses, the Huh7 cell was transiently transfected by the expression plasmid DNA including the Core gene, and the obtained cell extract was used as a positive control. Furthermore, a cell extract obtained from the Huh7 cell that was not transfected was used as a negative control. A sample extracted from each cell clone was subjected to SDS-PAGE and then blotted on a PVDF membrane (Immobilon™-P, Millipore), and the Core protein translated in the cell was analyzed by ECL (Amersham Pharmacia Biotech Pharmacia) using an anti-Core specific antibody (clone 2H9 antibody) and an HRP-labeled secondary antibody that recognizes the antibody. As a result, the Core protein was not detected in the infected cells. Therefore, it was determined that no daughter viral particle was produced in the infected cells. This means that, after the recombinant HCV-like particle produced by the method of the present invention once infects another cell, it is not further reproduced as a particle, thus not having an ability of further spreading infection to other cells (transmitting ability).

Industrial Applicability

[0161]

A recombinant HCV-like particle having an infecting property but not a transmitting property in which an HCV subgenomic RNA containing a desired foreign gene is packaged, and a method for producing the same can be provided by the present invention. Since such a recombinant HCV-like particle having an infecting property has an advantage of lacking a transmitting property, it can be used in gene therapy via *in vivo* or *ex vivo* gene introduction into hepatic or lymphoid cells or tissues of mammals, in particular, humans, or can be used as a viral vector for constructing a transgenic animal or as an attenuated vaccine.

Sequence Listing Free Text

[0162]

The sequences of SEQ ID NOS: 1 to 9 represent primers.

SEQUENCE LISTING IN ELECTRONIC FORM

In accordance with Section 111(1) of the Patent Rules, this description contains a sequence listing in electronic form in ASCII text format (file: 72813-295 Seq 01-APR-08 v1.txt).

A copy of the sequence listing in electronic form is available from the Canadian Intellectual Property Office.

The sequences in the sequence listing in electronic form are reproduced in the following table.

SEQUENCE TABLE

<110> Director General of National Institute of Infectious Diseases
Tokyo Metropolitan Organization for Medical Research
Toray Industries, Inc.

<120> Novel recombinant human hepatitis c virus-like particle and method for producing the same

<130> PH-2921-PCT

<140> PCT/JP2006/319573
<141> 2006-09-29

<150> JP 2005-287825
<151> 2005-09-30

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<170> PatentIn Ver. 2.1

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<213> Artificial Sequence

<220>

<223> Description of Artificial Sequence: primer

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<223> Inventor: Tanabe, Jun-ichi; Sone, Saburo; Wakita, Takaji
Inventor: Ishii, Takashi; Suzuki, Ryosuke; Suzuki, Tetsurou
Inventor: Miyamura Tatsuo

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<223> Description of Artificial Sequence: primer

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35

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<212> DNA

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<220>

<223> Description of Artificial Sequence: primer

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Lys Pro Gln Arg Lys Thr Lys Arg Asn Thr Asn Arg Arg Pro Glu Asp
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Arg Ser Thr Gly Lys Ala Trp Gly Lys Pro Gly Arg Pro Trp Pro Leu
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Tyr Gly Asn Glu Gly Leu Gly Trp Ala Gly Trp Leu Leu Ser Pro Arg
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Leu	His	Leu	His	Gln	Asn	Ile	Val	Asp	Val	Gln	Tyr	Met	Tyr	Gly	Leu	
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<210> 11

<211> 3033

<212> PRT

<213> Hepatitis C virus

<400> 11

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			20					25					30		
Gly	Val	Tyr	Leu	Leu	Pro	Arg	Arg	Gly	Pro	Arg	Leu	Gly	Val	Arg	Thr
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Thr	Arg	Lys	Thr	Ser	Glu	Arg	Ser	Gln	Pro	Arg	Gly	Arg	Arg	Gln	Pro
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Ile	Pro	Lys	Asp	Arg	Arg	Ser	Thr	Gly	Lys	Ala	Trp	Gly	Lys	Pro	Gly
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Arg	Pro	Trp	Pro	Leu	Tyr	Gly	Asn	Glu	Gly	Leu	Gly	Trp	Ala	Gly	Trp
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Ser	Gly	Ala	Ala	Arg	Ala	Val	Ala	His	Gly	Val	Arg	Val	Leu	Glu	Asp
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Phe	Leu	Leu	Ala	Leu	Leu	Ser	Cys	Ile	Thr	Val	Pro	Val	Ser	Ala	Ala
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Pro	Val	Ser	Pro	Asn	Met	Ala	Val	Arg	Gln	Pro	Gly	Ala	Leu	Thr	Gln
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Gln	Val	Phe	Ile	Val	Ser	Pro	Gln	Tyr	His	Trp	Phe	Val	Gln	Glu	Cys
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Val	Met	Arg	Val	Pro	Glu	Val	Ile	Ile	Asp	Ile	Val	Ser	Gly	Ala	His
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Trp	Gly	Val	Met	Phe	Gly	Leu	Ala	Tyr	Phe	Ser	Met	Gln	Gly	Ala	Trp
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Ala	Lys	Val	Ile	Val	Ile	Leu	Leu	Leu	Ala	Ala	Gly	Val	Asp	Ala	Gly
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Thr	Thr	Thr	Val	Gly	Gly	Ala	Val	Ala	Arg	Ser	Thr	Asn	Val	Ile	Ala
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Gly	Val	Phe	Ser	His	Gly	Pro	Gln	Gln	Asn	Ile	Gln	Leu	Ile	Asn	Thr
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Phe	Arg	Ile	Gly	Trp	Gly	Thr	Leu	Gln	Tyr	Glu	Asp	Asn	Val	Thr	Asn
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Pro	Glu	Asp	Met	Arg	Pro	Tyr	Cys	Trp	His	Tyr	Pro	Pro	Lys	Pro	Cys
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Pro	Ser	Pro	Val	Val	Val	Gly	Thr	Thr	Asp	Arg	Arg	Gly	Val	Pro	Thr
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Tyr	Thr	Trp	Gly	Glu	Asn	Glu	Thr	Asp	Val	Phe	Leu	Leu	Asn	Ser	Thr
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His	Pro	Asp	Ala	Thr	Tyr	Ile	Lys	Cys	Gly	Ser	Gly	Pro	Trp	Leu	Thr
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Pro	Lys	Cys	Leu	Val	His	Tyr	Pro	Tyr	Arg	Leu	Trp	His	Tyr	Pro	Cys
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Pro	Val	His	Gly	Gln	Ile	Gly	Val	Gly	Leu	Leu	Ile	Leu	Ile	Thr	Leu
			820					825					830		

Phe	Thr	Leu	Thr	Pro	Gly	Tyr	Lys	Thr	Leu	Leu	Gly	Gln	Cys	Leu	Trp	835	840	845
Trp	Leu	Cys	Tyr	Leu	Leu	Thr	Leu	Gly	Glu	Ala	Met	Ile	Gln	Glu	Trp	850	855	860
Val	Pro	Pro	Met	Gln	Val	Arg	Gly	Gly	Arg	Asp	Gly	Ile	Ala	Trp	Ala	865	870	875
Val	Thr	Ile	Phe	Cys	Pro	Gly	Val	Val	Phe	Asp	Ile	Thr	Lys	Trp	Leu	885	890	895
Leu	Ala	Leu	Leu	Gly	Pro	Ala	Tyr	Leu	Leu	Arg	Ala	Ala	Leu	Thr	His	900	905	910
Val	Pro	Tyr	Phe	Val	Arg	Ala	His	Ala	Leu	Ile	Arg	Val	Cys	Ala	Leu	915	920	925
Val	Lys	Gln	Leu	Ala	Gly	Gly	Arg	Tyr	Val	Gln	Val	Ala	Leu	Leu	Ala	930	935	940
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Ser	Asp	Trp	Ala	Ala	Ser	Gly	Leu	Arg	Asp	Leu	Ala	Val	Ala	Val	Glu	965	970	975
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Arg	Leu	Gly	Gln	Glu	Ile	Leu	Leu	Gly	Pro	Ala	Asp	Gly	Tyr	Thr	Ser	1010	1015	1020
Lys	Gly	Trp	Lys	Leu	Leu	Ala	Pro	Ile	Thr	Ala	Tyr	Ala	Gln	Gln	Thr	1025	1030	1035
Arg	Gly	Leu	Leu	Gly	Ala	Ile	Val	Val	Ser	Met	Thr	Gly	Arg	Asp	Arg	1045	1050	1055
Thr	Glu	Gln	Ala	Gly	Glu	Val	Gln	Ile	Leu	Ser	Thr	Val	Ser	Gln	Ser	1060	1065	1070
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26

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55232-7

CLAIMS:

1. A method for producing a recombinant hepatitis C virus-like particle comprising, introducing a vaccinia virus vector or an EF-1 α promotor carrying vector into a cell,

5 (i) wherein said cell carries a subgenomic RNA replicon comprising a nucleotide sequence comprising the 5' untranslated region, the nucleotide sequence coding for the NS3, NS4A, NS4B, NS5A, and NS5B proteins, and the 3' untranslated region of a genome RNA derived from con1 strain of hepatitis C virus and wherein said subgenomic RNA replicon does not comprise HCV structural genes, and

10 (ii) wherein said vaccinia virus vector or said EF-1 α promoter carrying vector expresses the Core, E1, E2, and p7 proteins derived from at least one virus strain selected from the group consisting of hepatitis C virus strains of genotype 1a, 1b, 2a, 2b, 3a, and 3b different from the hepatitis C virus strain as defined in the (i),

culturing the cell, and recovering the produced virus-like particle.

15 2. The method according to claim 1, wherein the hepatitis C virus strain of genotype 1a as defined in the (ii) is the H77c, 1, H, or HC-J1 strain.

3. The method according to claim 1, wherein the hepatitis C virus strain of genotype 1b as defined in the (ii) is the J1, TH, J, JT, or BK strain.

4. The method according to claim 1, wherein the hepatitis C virus strain of
20 genotype 2a as defined in the (ii) is the JFH1, HC-J6, JCH1, or J6CF strain.

5. The method according to claim 1, wherein the hepatitis C virus strain of genotype 3a as defined in the (ii) is the NZL1, K3a/650, 452, or E-b1 strain.

6. The method according to claim 1, wherein the hepatitis C virus strain of genotype 3b as defined in the (ii) is the Tr strain.

55232-7

7. The method according to claim 1, wherein the subgenomic RNA replicon further comprises at least one foreign gene and at least one internal ribosome entry site (IRES) sequence.
8. The method according to claim 7, wherein the foreign gene and the IRES
5 sequence are positioned between the 5' untranslated region and the sequence coding for the NS3 protein.
9. The method according to claim 1, wherein the cell is an animal cell.
10. The method according to claim 9, wherein the animal cell is the Huh7 cell, the HepG2 cell, or an established cell line derived from these cells.
- 10 11. A recombinant hepatitis C virus-like particle produced by the method according to claim 1, which has an infecting property but not a transmitting ability.

Fig. 1

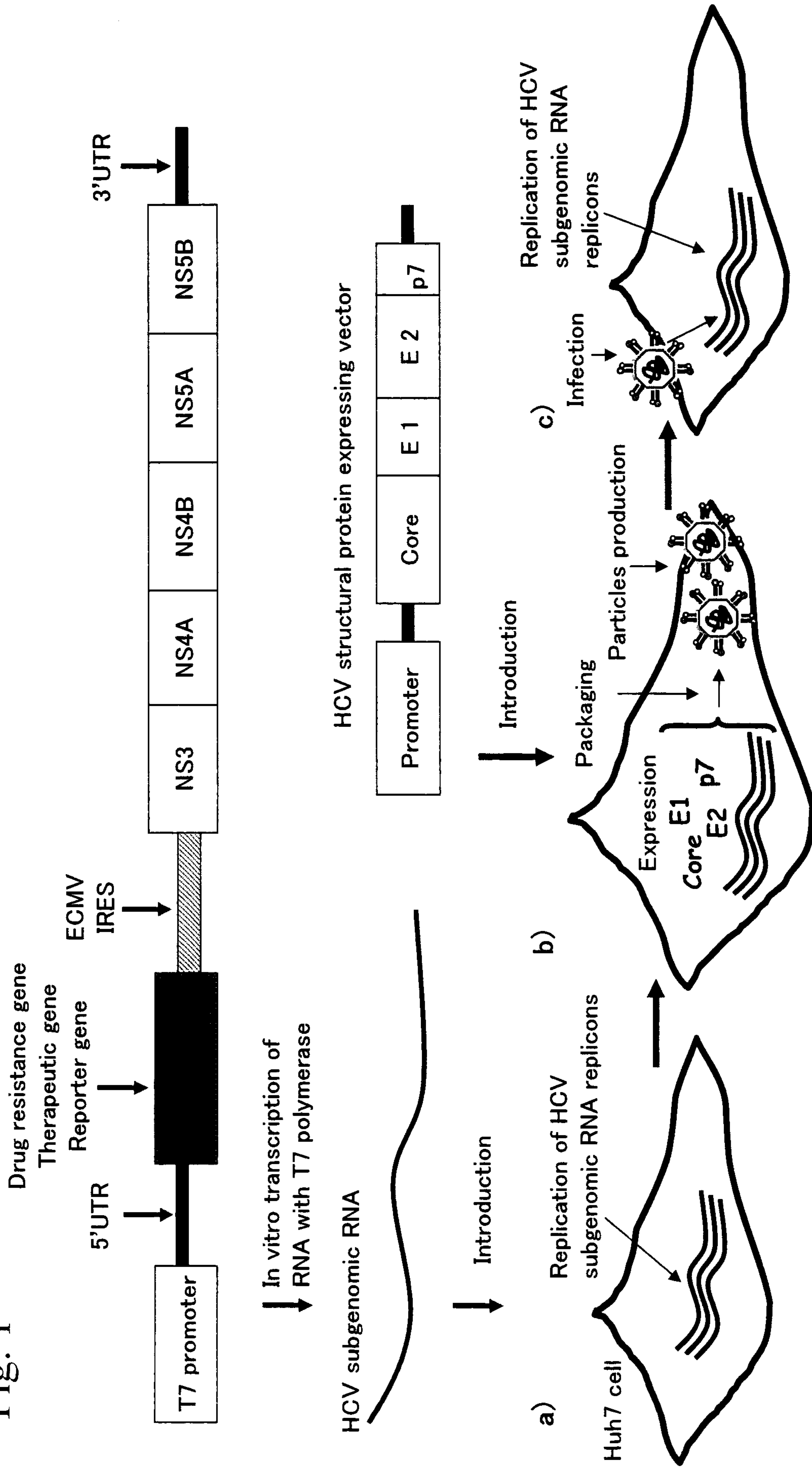
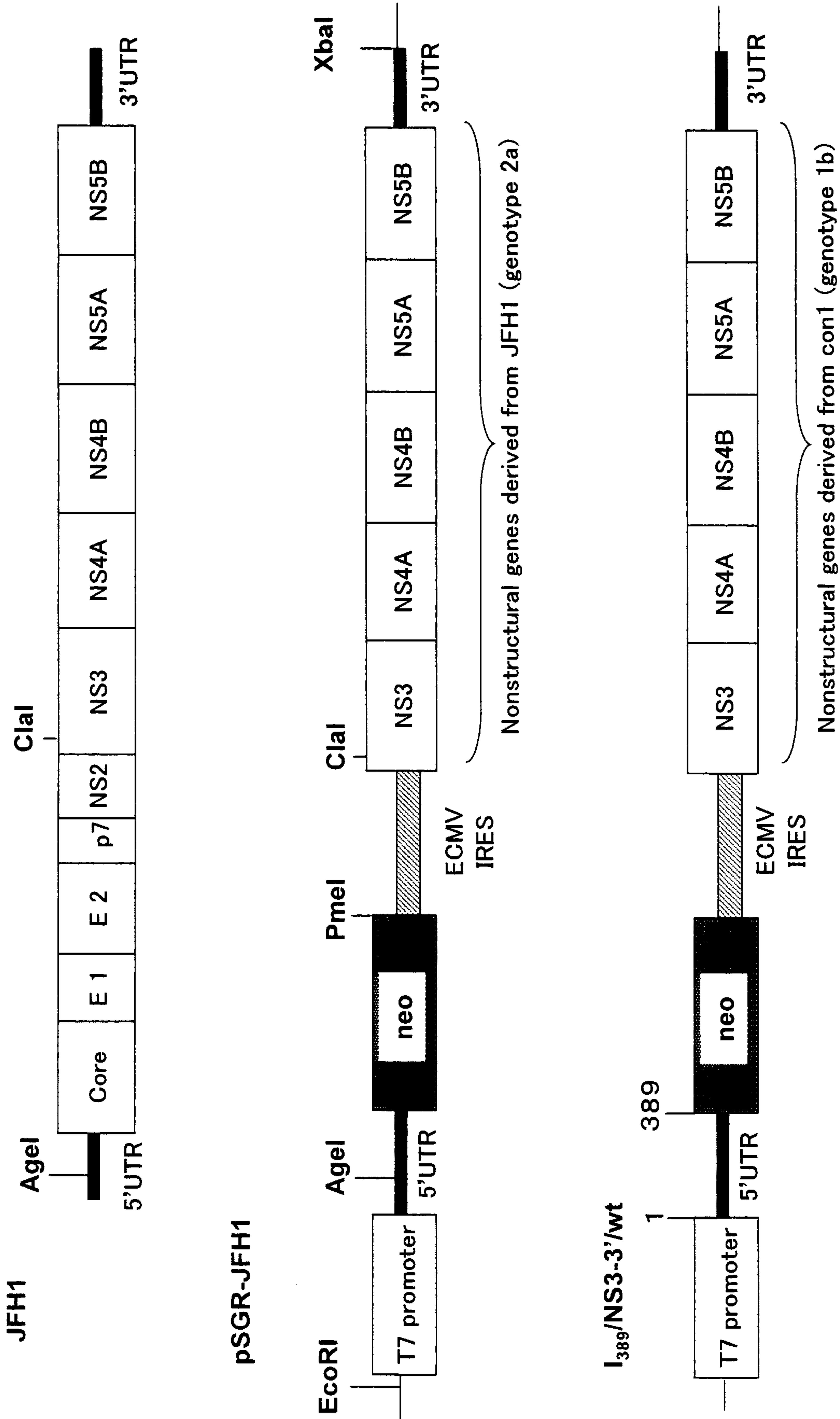


Fig. 2



Fi. 3

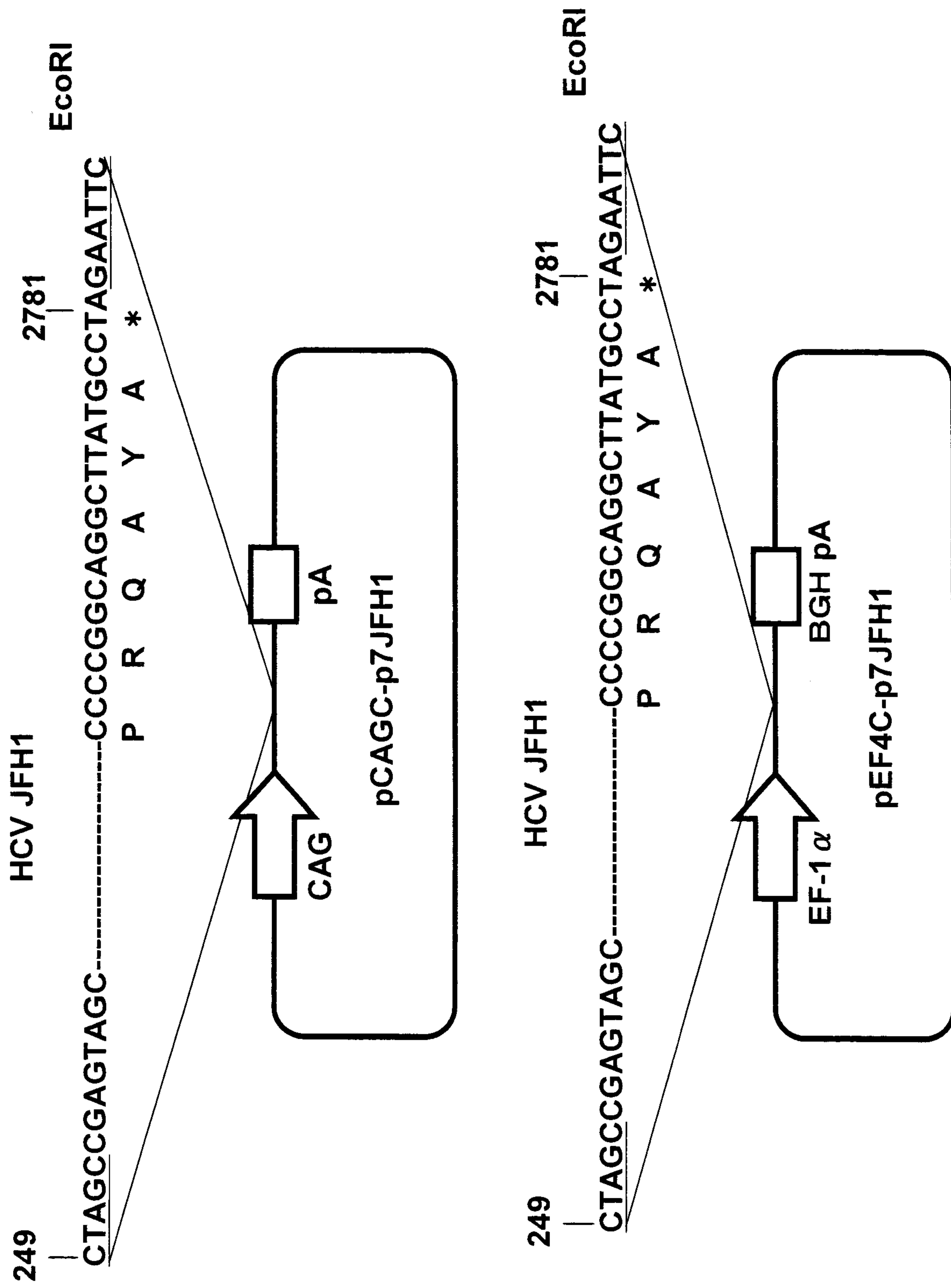


Fig. 4

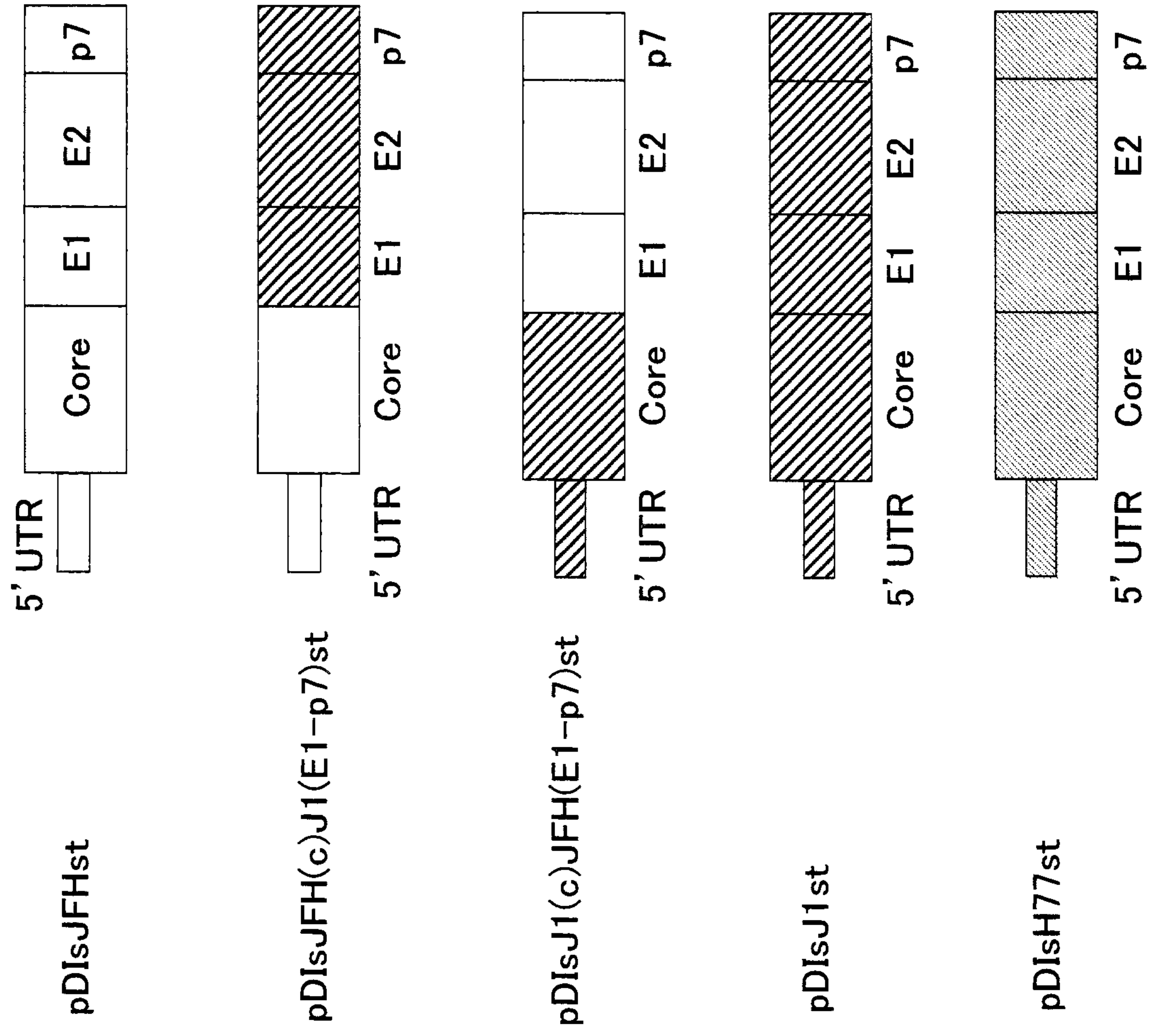


Fig. 5

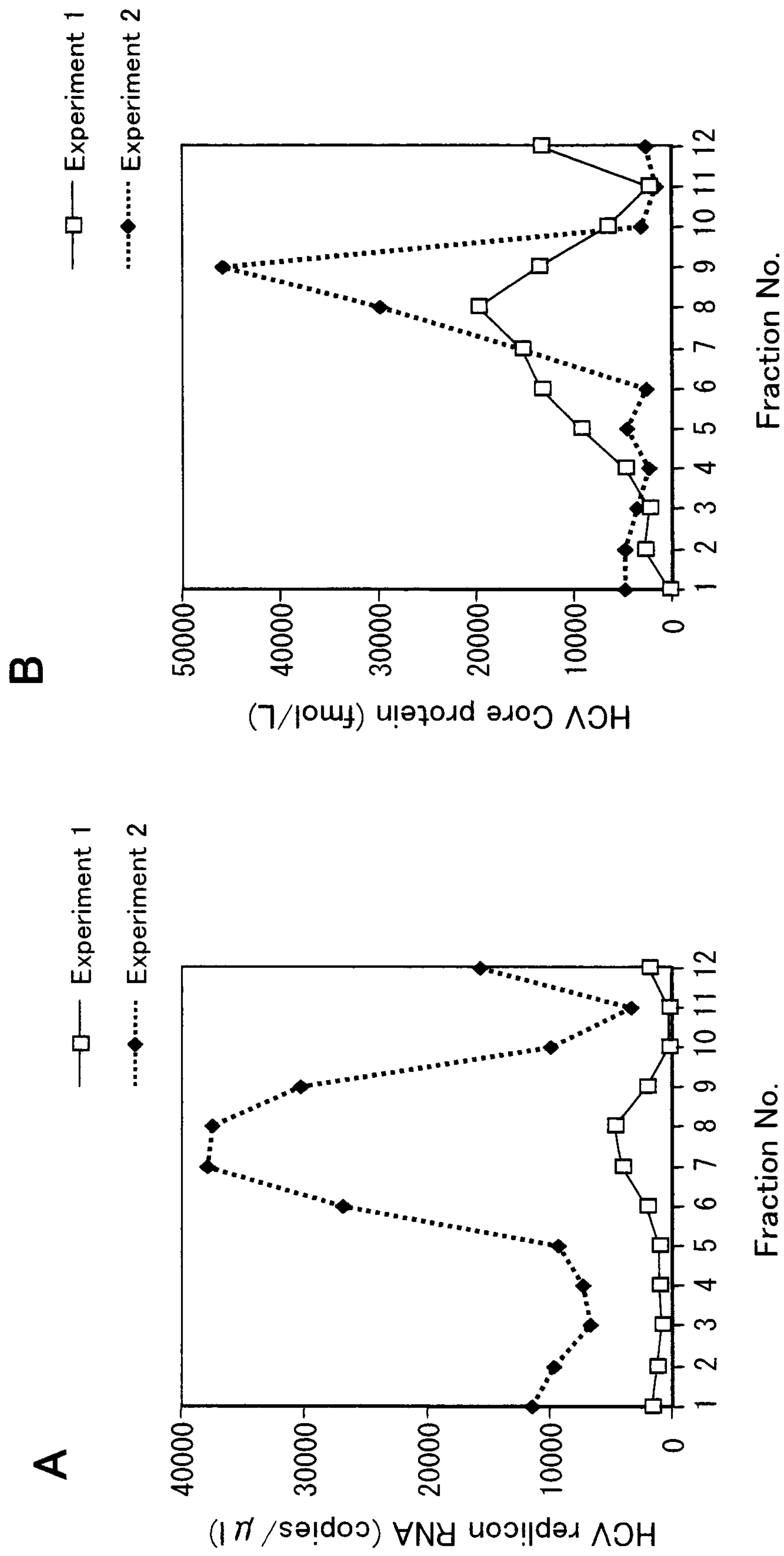
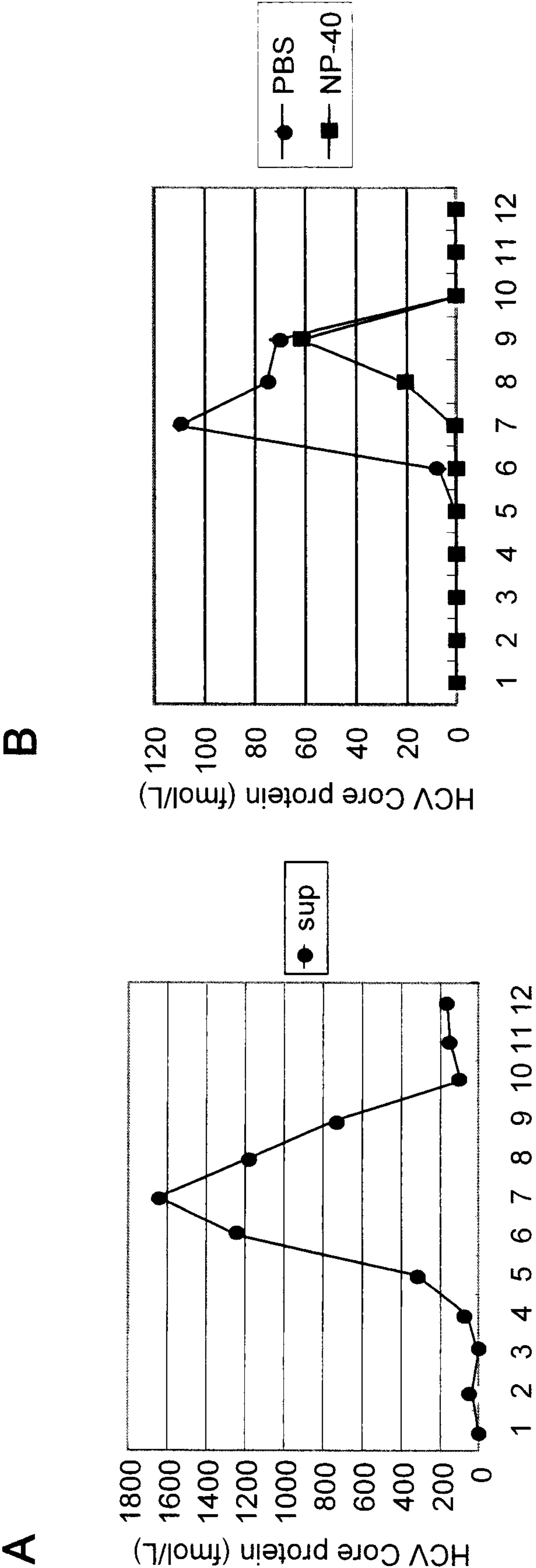
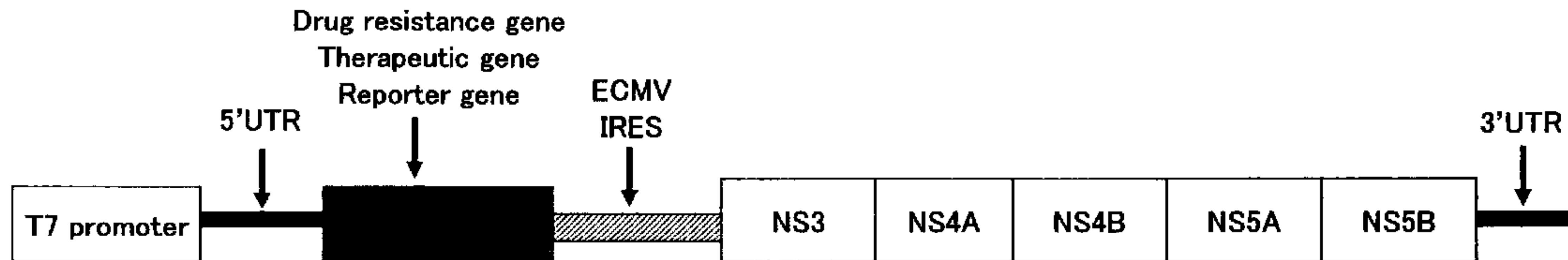


Fig. 6

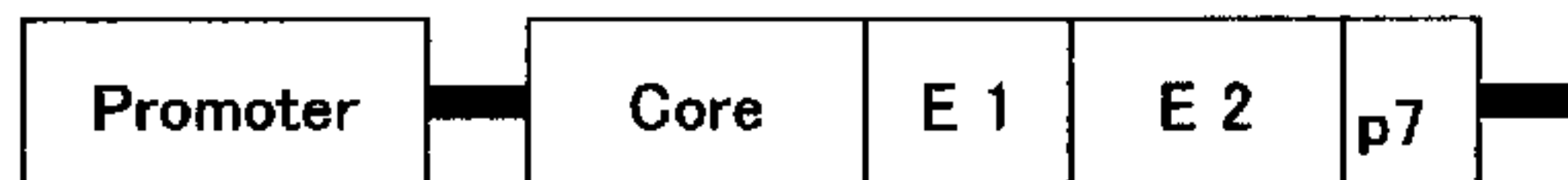




↓ In vitro transcription of
RNA with T7 polymerase

HCV subgenomic RNA

HCV structural protein expressing vector



Introduction

a)

Replication of HCV
subgenomic RNA replicons

Huh7 cell

Introduction

b)

Packaging

Particles production

Expression
Core E1
E2 p7

c)

Infection

Replication of HCV
subgenomic RNA
replicons

