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(54) Cloning vectors

(57) There is described a recombinant DNA cloning vector useful in *Streptomyces* and *E. coli,* comprising

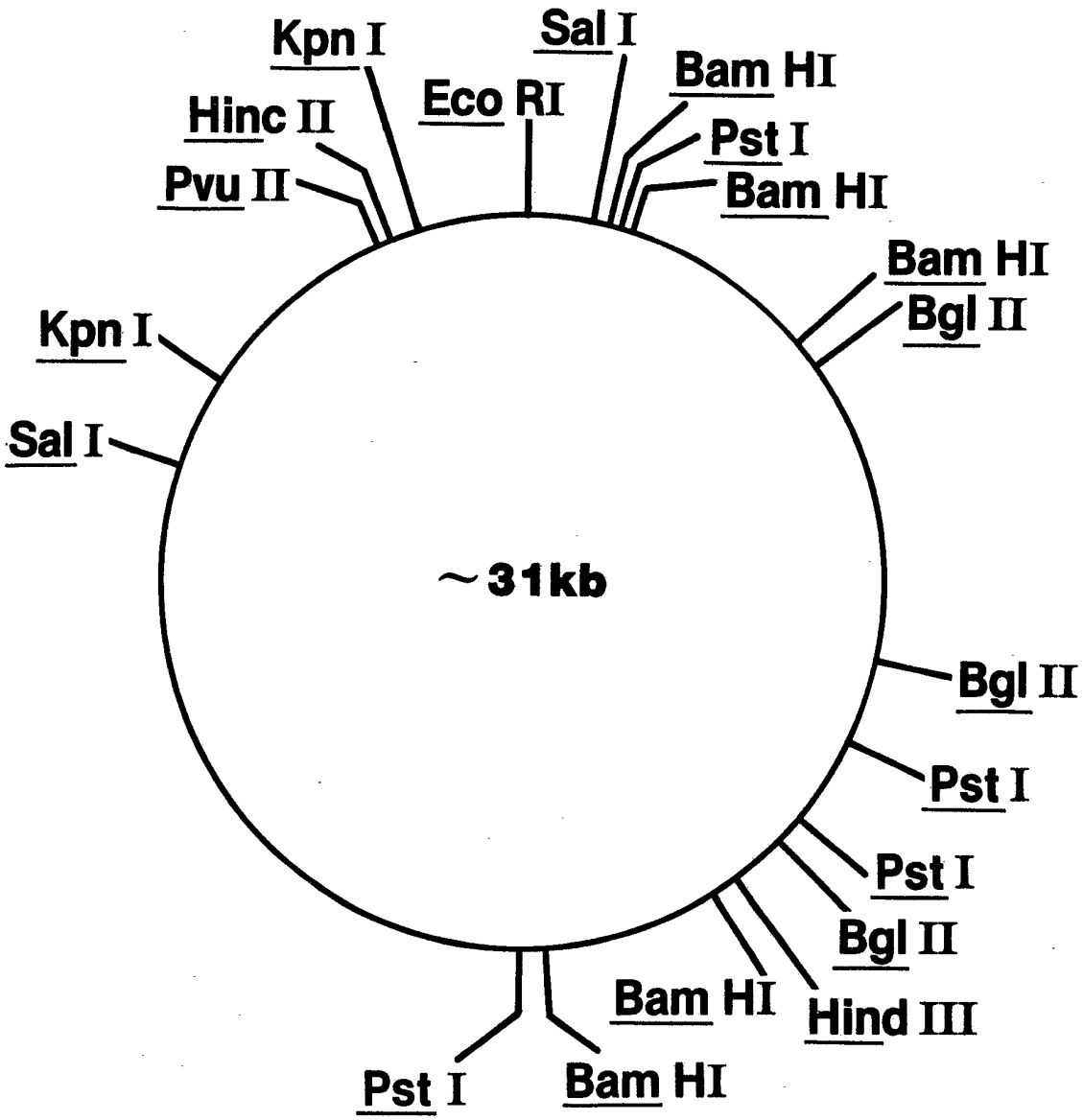
a) a functional origin of replication-containing restriction fragment of plasmid SCP2 or SCP2*,
b) a restriction fragment comprising an *E. coli* origin of replication,
c) one or more DNA segments that confer resistance to at least one antibiotic when transformed into a cell of *E. coli,* said cell being sensitive to the antibiotic for which resistance is conferred, and
d) one or more DNA segments that independently confer either or both of the *Streptomyces tra* function or resistance to at least one antibiotic when transformed into a cell of *Streptomyces,* said cell being sensitive to the antibiotic for which resistance is conferred.

Transformants and a method for detecting transformants of the vector are also disclosed.

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FIG. 1

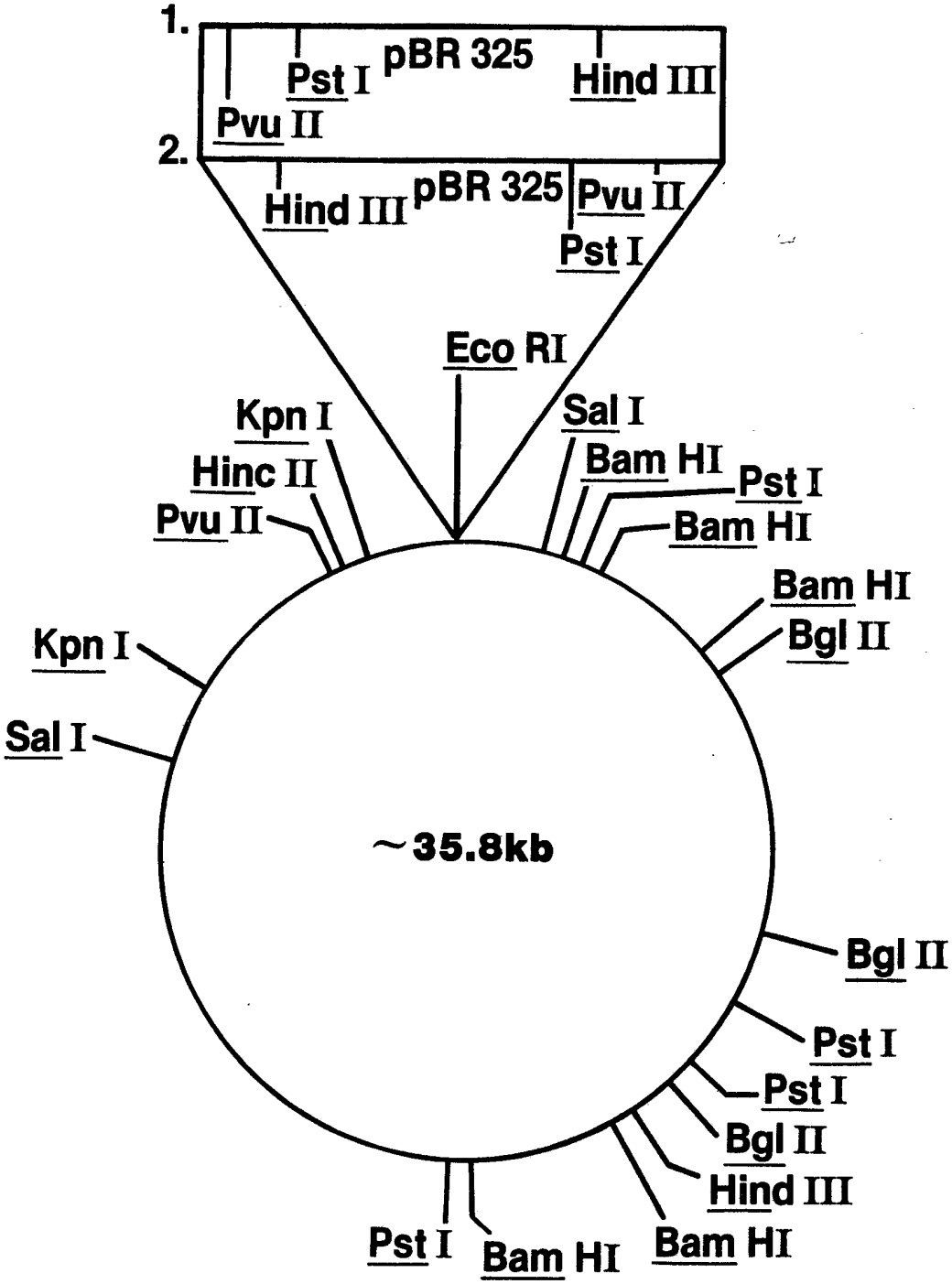
Restriction Site Map of Plasmids SCP2 and SCP2*



SCP2 and SCP2*

FIG. 2

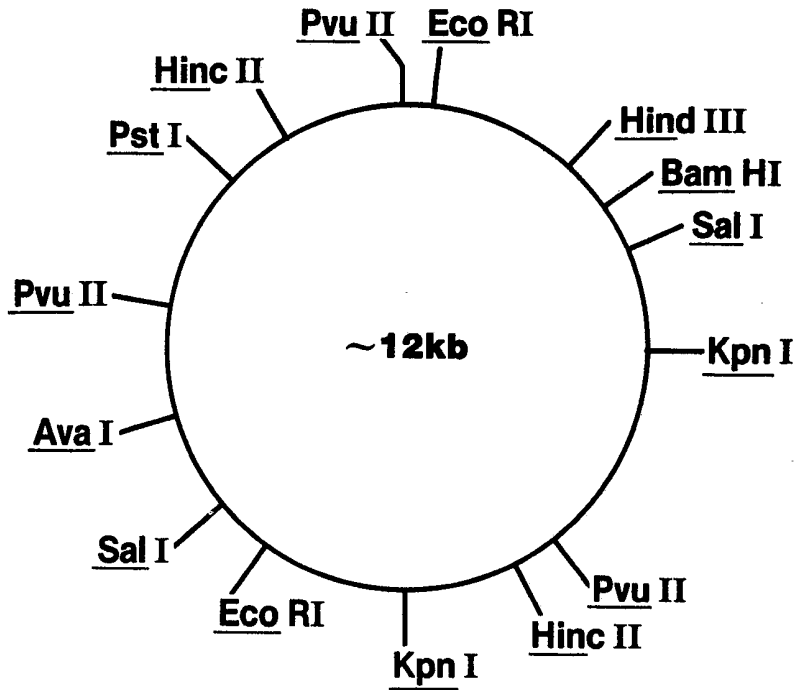
Restriction Site Map of Plasmids pJL120 and pJL121



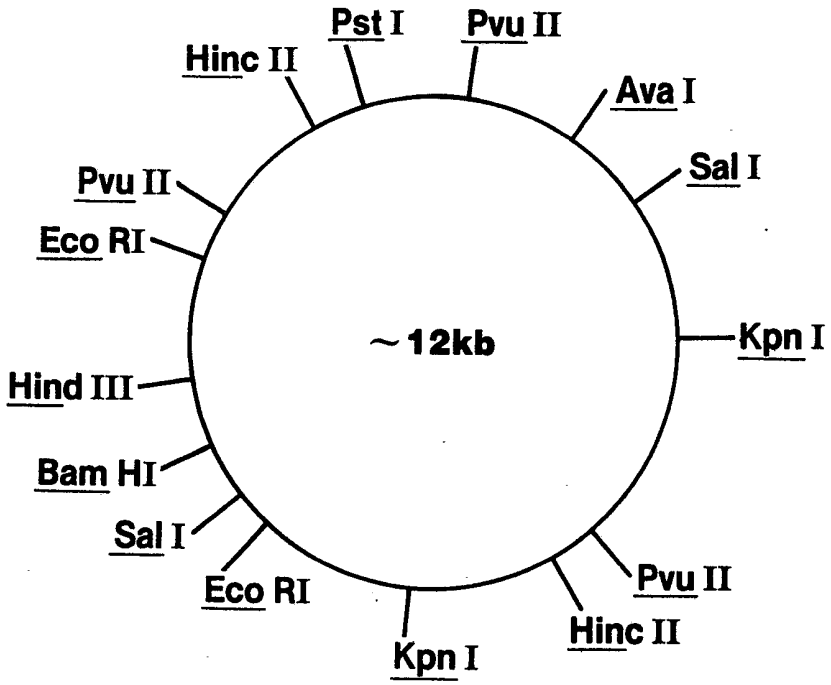
1. pJL 120
2. pJL 121

FIG. 3

Restriction Site Map of Plasmids pJL180 and pJL181



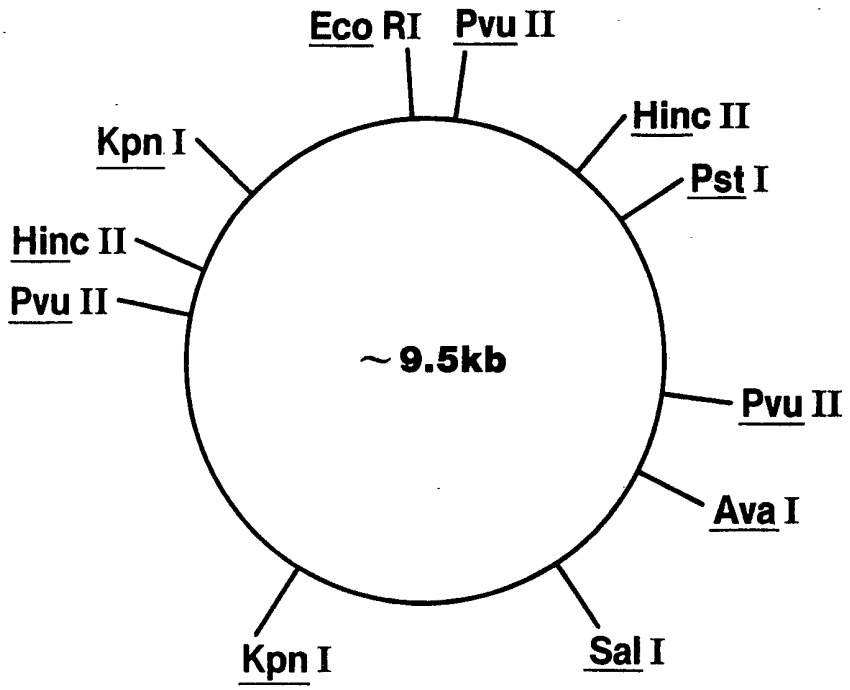
pJL 180



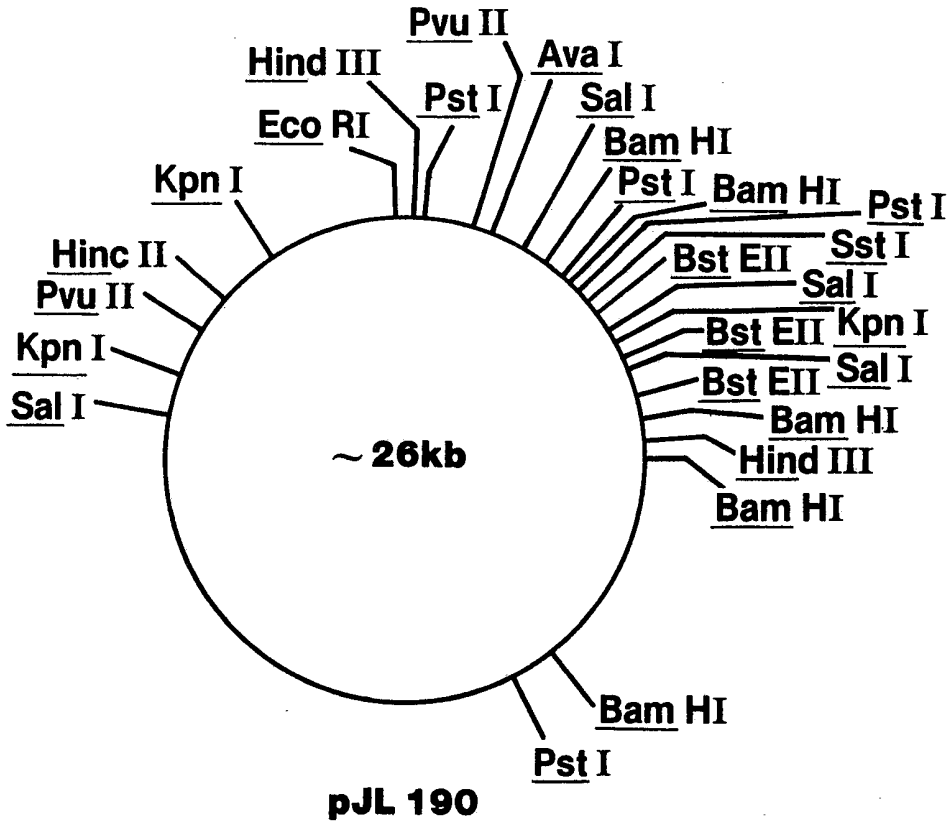
pJL 181

FIG. 4

Restriction Site Map of Plasmids pJL 125 and pJL 190



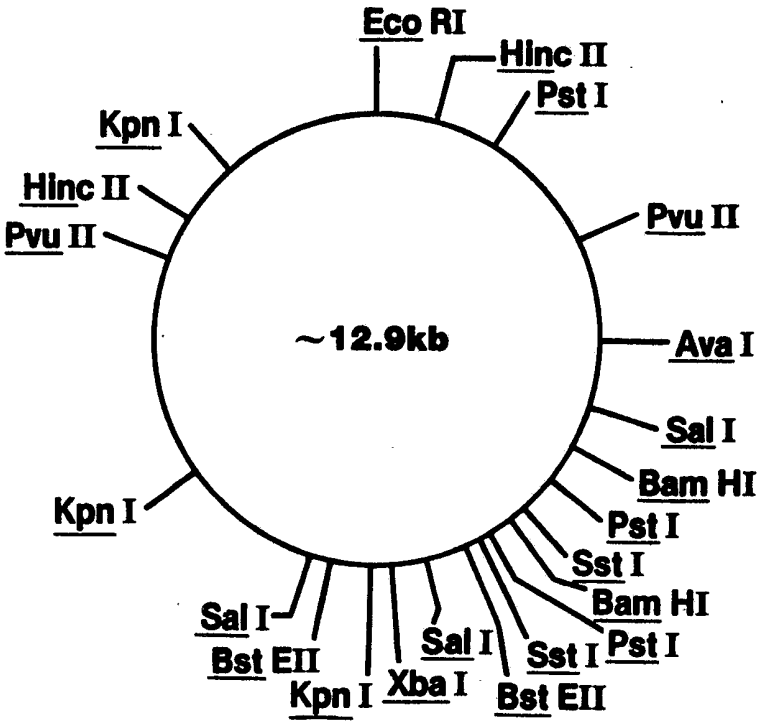
pJL 125



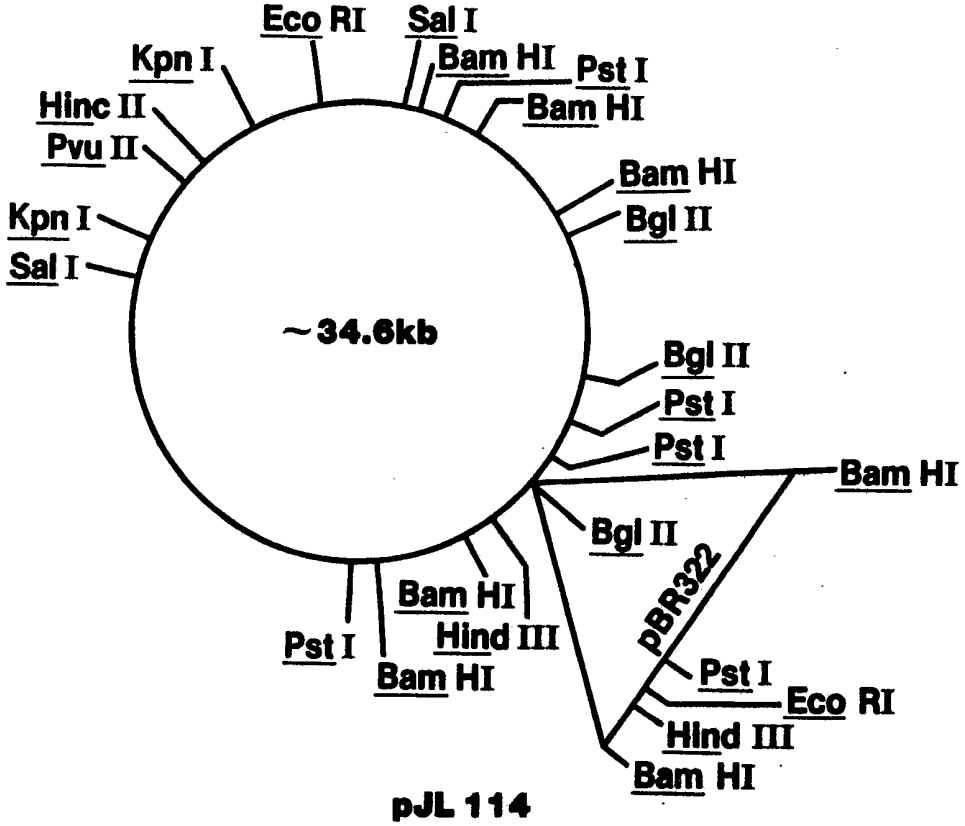
pJL 190

FIG. 5

Restriction Site Map of Plasmids pJL 195 and pJL 114



pJL 195



pJL 114

SPECIFICATION

Cloning vectors

The present invention relates to selectable novel recombinant DNA cloning vectors comprising a functional origin of replication-containing restriction fragment of plasmid SCP2 or SCP2* and a functional origin of replication-containing and antibiotic resistance-conferring restriction fragment of a plasmid that is functional in *E. coli.* The invention also relates to transformants and a method for detecting transformants of the aforementioned vectors.

The vectors to which this invention relates are particularly useful because they are small, versatile, and can be transformed and selected in *Streptomyces* or *E. coli.* Since over half of the clinically important antibiotics are produced by *Streptomyces* strains, it is desirable to develop cloning systems and vectors that are applicable to that industrially important group. Such vectors allow for the cloning of genes into *Streptomyces* both for increasing the yields of known antibiotics as well as for the production of new antibiotics and antibiotic derivatives.

The method of the present invention provides for the convenient selection of transformants. Since transformation is a very low frequency event, such a functional test is a practical necessity for determining which cell(s), of among the millions of cells, has acquired the plasmid DNA. This is important because DNA sequences that are non-selectable can be inserted into the vectors and, upon transformation, cells containing the vector and the particular DNA sequence of interest can be isolated by appropriate phenotypic selection.

For purposes of the present invention as disclosed and claimed herein, the following terms are as defined below.

Plasmid pLR1 or pLR4 3.4 kb *Bam*HI Restriction Fragment — the same 3.4 kb *Bam*HI neomycin resistance-conferring fragment contained in plasmid pIJ2.

Amp^R — the ampicillin resistant phenotype.

Amp^S — the ampicillin sensitive phenotype.

Tet^R — the tetracycline resistant phenotype.

Tet^S — the tetracycline sensitive phenotype.

CM^R — the chloramphenicol resistant phenotype.

CM^S — the chloramphenicol sensitive phenotype.

Neo^R — the neomycin resistant phenotype.

Neo^S — the neomycin sensitive phenotype.

$Thio^R$ — the thiostrepton resistant phenotype.

$Thio^S$ — the thiostrepton sensitive phenotype.

Neo^R, Neo^S, $Thio^R$, and $Thio^S$ refer only to results of tests in *Streptomyces* as used in this disclosure. Amp^R, Amp^S, Tet^R, Tet^S, Cm^R and Cm^S refer only to results of tests in *E. coli* as used in this disclosure.

The present invention specifically relates to recombinant DNA cloning vectors comprising:

a) a functional origin of replication-containing restriction fragment of plasmid SCP2 or SCP2*,

b) a restriction fragment comprising an *E. coli* origin of replication,

c) one or more DNA segments that confer resistance to at least one antibiotic when transformed into a cell of *E. coli,* said cell being sensitive to the antibiotic for which resistance is conferred, and

d) one or more DNA segments that independently confer either or both of the *Streptomyces tra* function or resistance to at least one antibiotic when transformed into a cell of *Streptomyces,* said cell being sensitive to the antibiotic for which resistance is conferred.

The recombinant DNA cloning vectors are made by a process which comprises ligating a functional origin of replication-containing restriction fragment of plasmid SCP2 or SCP2* and one or more DNA sequences comprising:

a) a restriction fragment comprising an *E. coli* origin of replication,

b) one or more DNA segments that confer resistance to at least one antibiotic when transformed into a cell of *E. coli,* said cell being sensitive to the antibiotic for which resistance is conferred, and

c) one or more DNA segments that independently confer either or both of the *Streptomyces tra* function or resistance to at least one antibiotic when transformed into a cell of *Streptomyces,* said cell being sensitive to the antibiotic for which resistance is conferred.

The invention further comprises transformants and a method for detecting transformants of the aforementioned vectors comprising:

1) mixing *Streptomyces* cells, under transforming conditions, with a recombinant DNA cloning vector, said vector comprising

a) an origin of replication and P gene-containing restriction fragment of plasmid SCP2 or SCP2*, and

b) a non-lethal DNA sequence cloned into the *Eco*RI restriction site of said P gene, and

2) growing said *Streptomyces* cells on a lawn of an indicator *Streptomyces* strain and selecting colonies that show the M pock phenotype.

The vectors of the present invention are best constructed by ligating an origin of replication-containing and *Streptomyces tra* function-conferring restriction fragment of plasmid SCP2 or SCP2*

into an *E. coli* origin of replication-containing and antibiotic resistance-conferring restriction fragment of an *E. coli* plasmid. Plasmids SCP2 and SCP2*, from which origins of replication are constructed, are each ~31 kb and show similar restriction patterns. Plasmid SCP2* arose as a spontaneous mutant of plasmid SCP2 and codes for a selectable colony pock morphology. Although the pock is distinguishable from that of plasmid SCP2, in other ways plasmids SCP2 and SCP2* are virtually identical.

Since the present disclosure teaches that the *Stremptomyces tra* function and the origin of replication of plasmids SCP2 and SCP2* are within their respective ~5.4 kb *Eco*RI-*Sal*I restriction fragments, a variety of different origin of replication-containing and *Streptomyces tra* function-conferring fragments can be generated. This is accomplished by digestion with restriction enzymes that cut outside the ~5.4 kb *Eco*RI-*Sal*I region. A detailed restriction site map of plasmid SCP2* (and thus also plasmid SCP2) is presented in Figure 1 of the accompanying drawings.

Plasmids SCP2 and SCP2* can be conventionally isolated respectively from the *Streptomyces coelicolor* A3(2) and *Streptomyces coelicolor* M110 strains deposited and made part of the permanent stock culture collection of the Northern Regional Research Laboratory, Peoria, Illinois. *Streptomyces coelicolor* A3(2) is available to the public as a preferred source and stock reservoir of plasmid SCP2 under the accession number 15042. *Streptomyces coelicolor* M110 is available to the public as a preferred source and stock reservoir of plasmid SCP2* under the accession number 15041.

Many *tra* function-conferring and origin of replication-containing restriction fragments of plasmids SCP2 and SCP2* can be constructed. Those specifically exemplified, for illustrative purposes, include the ~5.4 kb *Eco*RI-*Sal*I, the ~6.0 kb *Sal*I, the ~19 kb *Eco*RI-*Hind*III, and the ~31 kb *Eco*RI restriction fragments of plasmid SCP2* and the ~31 kb *Bgl*II restriction fragment of plasmid SCP2. The aforementioned plasmid SCP2* and SCP2 fragments were respectively ligated to an origin of replication-containing and antibiotic resistance-conferring fragment of *E. coli* plasmids pBR325 and pBR322. Those skilled in the art will recognize that although not required, it is convenient for both the DNA segment that confers antibiotic resistance in *E. coli* and the *E. coli* origin of replication to comprise a restriction fragment of the same *E. coli* plasmid.

Thus, for convenience and ease of construction, the ~31 kb *Eco*RI fragment of plasmid SCP2* and the ~6 kb *Eco*RI fragment of plasmid pBR325 were ligated to form illustrative plasmids pJL120 and pJL121. Recombinant plasmids of two orientations result because the fragments can be ligated in either direction. Similarly, ligation of the SCP2* ~6.0 kb *Sal*I fragment and the ~6 kb *Sal*I fragment of pBR325 results in the illustrative plasmids pJL180 and pJL181; ligation of the SCP2* ~5.4 kb *Eco*RI-*Sal*I fragment and the ~4.8 kb *Eco*RI-*Sal*I fragment of pBR325 results in the illustrative plasmid pJL125; and ligation of the SCP2 *Bam*HI digest and the ~4.4 kb *Bam*HI fragment of plasmid pBR322 results in the illustrative plasmid pJL114.

All of the aforementioned vectors are readily selectable in each of *E. coli* and *Streptomyces.* For example in *E. coli,* plasmids pJL120 and pJL121 confer ampicillin and tetracycline resistance; plasmids pJL180 and pJL181 confer ampicillin and chloramphenicol resistance; and plasmids pJL125 and pJL114 confer only ampicillin resistance. Therefore, the vectors are conventionally selectable in the *E. coli* host system by adding the appropriate antibiotic to the culture medium.

The aforementioned vectors also produce the 'pock' phenotype and therefore are conventionally selectable in *Streptomyces.* The 'pock' phenotype is an assayable trait and known phenomenon (Bibb and Hopwood, 1981, J. Gen. Microbiol. 126:427) associated with lethal zygosis and the *tra* function (tra=genes coding for sexual transmissability) of *Streptomyces* sex factors. Three distinct 'pock' morphologies are associated with transformants, when plated on an appropriate indicator strain, of plasmids SCP2, SCP2*, and SCP2 and SCP2* derivatives. The colony morphology identified with the wild-type SCP2 and the mutant SCP2* are respectively designated herein as P and P*. A third and heretofore unknown pock morphology results from cloning into the *Eco*RI restriction site of SCP2 or SCP2*. Such an insertion inactivates the P gene and unexpectedly results in a morphologically distinguishable minipock phenotype, designated herein as M, when transformants are appropriately plated. "Minipock" is a pock of significantly smaller size than pocks caused by either SCP2 or SCP2*.

The present invention thus provides a novel method for detecting transformants comprising:

1) mixing *Streptomyces* cells, under transforming conditions, with a recombinant DNA cloning vector, said vector comprising

a) an origin of replication and P gene-containing restriction fragment of plasmid SCP2 or SCP2*, and

b) a non-lethal DNA sequence cloned into the *Eco*RI restriction site of said P gene, and

2) growing said *Streptomyces* cells on a lawn of an indicator *Streptomyces* strain and selecting colonies that show the M pock phenotype.

Only transformed *Streptomyces* cells will show the M pock phenotype and therefore transformants can be readily identified and selected. Those skilled in the art will quickly recognize, from the above description of the present pJL vectors, that plasmids pJL120, pJL121, and pJL125 code for M phenotype, that plasmids pJL180 and pJL181 code for P* phenotype, and that plasmid pJL114 codes for P phenotype. Appropriate indicator strains for expression of the pock phenotype are known

and include the various SCP2$^-$ and SCP2*$^-$ strains as illustrated in the Examples below. The present vectors are thus selectable and extremely useful in *Streptomyces*.

The aforementioned plasmids can also be provided with a DNA segment that confers antibiotic resistance in *Streptomyces*. Such derivatives, specifically exemplified for illustrative purposes by plasmids pJL190 and pJL195, express an additional selectable phenotype. Plasmid pJL190 was constructed by ligating the neomycin resistance-conferring ~7.7 kb *Eco*RI-*Hind*III fragment of plasmid pLR4 to the ~19 kb *Eco*RI-*Hind*III fragment of plasmid pJL121. Plasmid pJL195 was constructed by ligating the pLR4 ~7.5 kb *Eco*RI-partial *Sal*I fragment to the ~5.4 kb *Eco*RI-*Sal*I fragment of plasmid pJL125. The latter pJL125 plasmid comprises the largest (5.4 kb) *Eco*RI-*Sal*I fragment of plasmid pSCP2* and was constructed by *Sal*I deletion of plasmid pJL121. Illustrative plasmids pJL190 and pJL195, in addition to neomycin resistance, also express the M phenotype as discussed above.

Plasmid pLR4, the source of the neomycin resistance conferring fragments, is ~7.7 kb and is constructed by ligating *Bam*HI-treated plasmids pBR322 and pLR1. Plasmid pLR1 is ~14.8 kb and is constructed by ligating *Hind*III-treated plasmid pIJ2, disclosed in Thompson *et al.*, 1980, Nature 286:525, to *Hind*III-treated plasmid pBR322. As is readily apparent to those skilled in the art, both plasmids pLR4 and pLR1 contain the same neomycin resistance gene and thus either plasmid can be used for constructing the aforementioned pJL neomycin resistant vectors.

An additional neomycin resistance-conferring plasmid, designated as pJL192, was isolated as a spontaneous mutant of plasmid pJL190 resident in *Streptomyces griseofuscus*. Plasmid pJL192 specifies resistance to elevated levels of neomycin and therefore comprises a novel neomycin resistance gene which is distinguishable from the resistance gene comprising plasmids pJL190, pJL195, pIJ2, pLR4, and pLR1. In a similar manner, an additional neomycin resistance-conferring plasmid, designated as pJL199, was isolated as a spontaneous mutant of plasmid pJL195. Those skilled in the art will recognize that the novel neomycin resistance gene of plasmid pJL192 or pJL199 can be readily excised and ligated to other vectors. The gene allows for improved and more efficient selection of transformants. As in the case of plasmids pJL190 and pJL195, transformants of plasmids pJL192 and pJL199 express the M phenotype when plated on an appropriate indicator strain.

Plasmid pJL192 can be conventionally isolated from *E. coli* K12 C600R_k-M_k-/pJL192, a strain deposited and made part of the permanent stock culture collection of the Northern Regional Research Laboratory, Peoria, Illinois. It is available to the public as a stock reservoir and preferred source of plasmid pJL192 under the accession number B-15040.

A DNA segment that confers resistance to antibiotic thiostrepton, exemplified by the ~1.35 kb *Bam*HI restriction fragment of plasmid pLR2, can also be used with or substituted for the neomycin resistance-conferring segment. Plasmid pLR2, the source of the thiostrepton resistance conferring fragment, is ~18.7 kb and is constructed by ligating *Hind*III treated plasmid pIJ6, disclosed in Thompson *et al.*, 1980, Nature 286:525, to *Hind*III treated plasmid pBR322. Plasmid pLR2 is functional in *E. coli* and therefore can be amplified and isolated conveniently for subsequent manipulation.

For convenience and ease of construction, the thiostrepton resistance conferring ~1.35 kb *Bam*HI fragment of plasmid pLR2 was ligated into the *Bam*HI restriction site of plasmid pBR328 to form plasmid pJL193. The ~1 kb *Bcl*I restriction fragment of pJL193 contains the thiostrepton resistance-conferring DNA segment. Therefore, ligation, as described in Examples 52—56, results in vectors that are within the scope of the present invention.

Various plasmid SCP2 and SCP2* restriction fragments can be used for purposes of constructing the present invention provided that the origin of replication contained in their respective ~5.4 kb *Eco*RI-*Sal*I restriction fragments is present. Such additional plasmid SCP2 and SCP2* restriction fragments include, but are not limited to, the ~6 kb *Sal*I, ~15 kb *Pst*I, ~23 kb *Bgl*II, ~15 kb *Bam*HI, ~14 kb *Eco*RI-*Pst*I, ~13 kb *Eco*RI-*Bam*HI, and ~15 kb *Pst*I-*Bam*HI fragments. These fragments contain the *Streptomyces tra* function and can be ligated to a functional *E. coli* origin of replication-containing and antibiotic resistance-conferring restriction fragment of an *E. coli* plasmid. Such *E. coli* plasmids include, for example, plasmids pBR322, pBR324, pBR325, pBR327, pBR328 and the like. Therefore, the present invention is not limited to the use of either plasmid pBR322 or pBR325 as exemplified in several pJL constructions.

Although the neomycin and thiostrepton antibiotic resistance-conferring DNA segments exemplified herein are respectively the ~7.7 kb *Eco*RI-*Hind*III and the ~7.5 kb *Eco*RI-partial *Sal*I fragments of plasmid pLR4 and the pLR2 ~1.35 *Bam*HI and the pJL193 ~1 kb *Bcl*I fragments, those skilled in the art can construct and use other DNA segments that also confer resistance to neomycin or thiostrepton. Other neomycin resistance-conferring DNA segments of plasmid pLR1 include, for example, the ~3.4 kb *Bam*HI restriction fragment, the ~3.5 kb *Pst*I restriction fragment, and the larger of the *Sst*I-*Kpn*I subfragments of the ~3.4 kb *Bam*HI restriction fragment. Other thiostrepton resistance-conferring segments include, for example, the ~13 kb *Pst*I fragment of plasmid pLR2. Still other DNA segments conferring resistance to the same or to different antibiotics such as, for example, hygromycin, viamycin, tylosin, erythromycin and the like, can also be constructed and used by those skilled in the art. In addition, various functional derivatives of the above described antibiotic resistance-

conferring DNA segments can be constructed by adding, eliminating, or substituting nucleotides in accordance with the genetic code.

Ligation of the aforementioned derivatives, or any of the other antibiotic resistance-conferring DNA segments, to a vector comprising an *E. coli* antibiotic resistance-conferring DNA segment, an *E. coli* origin of replication-containing restriction fragment, and also an origin of replication-containing restriction fragment of plasmids SCP2 or SCP2*, results in plasmids that are within the scope of the present invention. Therefore, an antibiotic resistance-conferring DNA segment can be used as a selectable marker in place of the *Streptomyces tra* function and associated pock phenotype. Thus, the present vectors are not limited to the use of *tra* alone or in combination with an antibiotic resistance-conferring DNA segment. In addition, a particular antibiotic resistance-conferring DNA segment is not limited to a single position on the present chimeric plasmids but can be ligated or inserted at varying sites provided that an origin of replication or other critical plasmid controlled physiological functions are not disrupted. Those skilled in the art understand or can readily determine which sites are advantageous for ligation or insertion of a particular DNA segment.

The various restriction fragments of plasmids SCP2, SCP2*, pBR325, pBR322 and the like, and also the various antibiotic resistance-conferring DNA segments comprising the present vectors, can be modified to facilitate ligation. For example, molecular linkers can be provided to some or all of the aforementioned DNA fragments. Thus, specific sites for subsequent ligation can be constructed conveniently. In addition, the origin of replication-containing restriction fragments can also be modified by adding, eliminating, or substituting certain nucleotides to alter characteristics and to provide a variety of restriction sites for ligation of DNA. Those skilled in the art understand nucleotide chemistry and the genetic code and thus which nucleotides are interchangeable and which DNA modifications are desirable for a specific purpose.

The recombinant DNA cloning vectors that contain the SCP2 or SCP2* *Streptomyces tra* function are self transmissable and thus readily transferred during mating between transformed and non-transformed *Streptomyces* taxa. This is advantageous because the present vectors therefore can be transformed not only by protoplast transformation but also by conventional genetic crosses. Consequently, the vectors are useful in *Streptomyces* strains which are difficult to protoplast thus greatly expanding the number of hosts in which genetic manipulation and DNA cloning can be done.

More importantly, DNA-libraries constructed in the present vectors can be conveniently and rapidly screened for interesting genes by conventional replica-plate mating procedures. Without the *tra* function, DNA must be isolated from each of the thousands of clones in the library and transformed into appropriate strains to identify clones that contain desirable genes. Since there are no broadly applicable phage vectors for use in *Streptomyces,* the present tra^+ vectors fulfill the general cloning and screening role analogous to that of bacteriophage λ in replica-plate transduction for screening gene libraries in *E coli.* Desirable genes can thus be readily identified by the replica-plate mating procedure and then easily amplified by shuttling into *E. coli* as described in Example 20C below.

The vectors of the present invention are broadly applicable and are transformed into host cells of many *Streptomyces* taxa, particularly restrictionless strains of economically important taxa that produce antibiotics such as aminoglycoside, macrolide, β-lactam, polyether, and glycopeptide antibiotics. Such restrictionless strains are readily selected and isolated from *Streptomyces* taxa by conventional procedures well known in the art (Lomovskaya *et al.,* 1980, Microbiological Reviews 44:206). Host cells of restrictionless strains lack restriction enzymes and therefore do not cut or degrade plasmid DNA upon transformation. For purposes of the present application, host cells containing restriction enzymes that do not cut any of the restriction sites of the present vectors are also considered restrictionless.

Preferred host cells of restrictionless strains of *Streptomyces* taxa that produce aminoglycoside antibiotics and in which the present vectors are especially useful and are transformed, include restrictionless cells of, for example: *S. kana-myceticus* (kanamycins), *S. chrestomyceticus* (aminosidine), *S. griseoflavus* (antibiotic MA 1267), *S. microsporeus* (antibiotic SF-767), *S. ribosidificus* (antibiotic SF733), *S. flavopersicus* (spectinomycin), *S. spectabilis* (actinospectacin), *S. rimosus* forma *paromomycinus* (paramomycins, catenulin), *S. fradiae* var. *italicus* (aminosidine), *S. bluensis* var. *bluensis* (bluensomycin), *S. catenulae* (catenulin), *S. olivoreticuli* var. *cellulophilus* (destomycin A), *S. tenebrarius* (tobramycin, apramycin), *S. lavendulae* (neomycin), *S. albogriseolus* (neomycins), *S. albus* var. *metamycinus* (metamycin), *S. hygroscopicus* var. *sagamiensis* (spectinomycin), *S. bikiniensis* (streptomycin), *S. griseus* (streptomycin), *S. erythrochromogenes* var. *narutoensis* (streptomycin), *S. poolensis* (streptomycin), *S. galbus* (streptomycin), *S. rameus* (streptomycin), *S. olivaceus* (streptomycin), *S. mashuensis* (streptomycin), *S. hygroscopicus* var. *limoneus* (validamycins), *S. rimofaciens* (destomycins), *S. hygroscopicus* forma *glebosus* (glebomycin), *S. fradiae* (hybrimycins neomycins), *S. eurocidicus* (antibiotic A16316-C), *S. aquacanus* (N-methyl hygromycin B), *S. crystallinus* (hygromycin A), *S. noboritoensis* (hygromycin), *S. hygroscopicus* (hygromycins), *S. atrofaciens* (hygromycin), *S. kasugaspinus* (kasugamycins), *S. kasugaensis* (kasugamycins), *S. netropsis* (antibiotic LL-AM31), *S. lividus* (lividomycins), *S. hofuensis* (seldomycin complex), and *S. canus* (ribosyl paromamine).

Preferred host cells of restrictionless strains of *Streptomyces* taxa that produce macrolide

antibiotics and in which the present vectors are especially useful and are transformed, include restrictionless cells of, for example: *S. caelestis* (antibiotic M188), *S. platensis* (platenomycin), *S. rochei* var. *volubilis* (antibiotic T2636), *S. venezuelae* (methymycins), *S. griseofuscus* (bundlin), *S. narbonensis* (josamycin, narbomycin), *S. fungicidicus* (antibiotic NA-181), *S. griseofaciens* (antibiotic PA133A, B), *S. roseocitreus* (albocycline), *S. bruneogriseus* (albocycline), *S. roseochromogenes* (albocycline), *S. cinerochromogenes* (cineromycin B), *S. albus* (albomycetin), *S. felleus* (argomycin, picromycin), *S. rochei* (lankacidin, borrelidin), *S. violaceoniger* (lankacidin), *S. griseus* (borrelidin), *S. maizeus* (ingramycin), *S. albus* var. *coilmyceticus* (coleimycin), *S. mycarofaciens* (acetyl-leukomycin, espinomycin), *S. hygroscopicus* (turimycin, relomycin, maridomycin, tylosin, carbomycin), *S. griseospiralis* (relomycin), *S. lavendulae* (aldgamycin), *S. rimosus* (neutramycin), *S. deltae* (deltamycins), *S. fungicidicus* var. *espinomyceticus* (espinomycins), *S. furdicidicus* (mydecamycin), *S. eurocidicus* (methymycin), *S. griseolus* (griseomycin), *S. flavochromogenes* (amaromycin, shincomycins), *S. fimbriatus* (amaromycin), *S. fasciculus* (amaromycin), *S. erythreus* (erythromycins), *S. antibioticus* (oleandomycin), *S. olivochromogenes* (oleandomycin), *S. spinichromogenes* var. *suragaoensis* (kujimycins), *S. kitasatoensis* (leucomycin), *S. narbonensis* var. *josamyceticus* (leucomycin A3, josamycin), *S. albogriseolus* (mikonomycin), *S. bikiniensis* (chalcomycin), *S. cirratus* (cirramycin), *S. djakartensis* (niddamycin), *S. eurythermus* (angolamycin), *S. fradiae* (tylosin, lactenocin, macrocin), *S. goshikiensis* (bandamycin), *S. griseoflavus* (acumycin), *S. halstedii* (carbomycin), *S. tendae* (carbomycin), *S. macrosporeus* (carbomycin), *S. thermotolerans* (carbomycin), *S. albireticuli* (carbomycin), and *S. ambofaciens* (spiramycin).

Preferred host cells of restrictionless strains of *Streptomyces* taxa that produce β-lactam antibiotics and in which the present vectors are especially useful and are transformed, include restrictionless cells of, for example: *S. lipmanii* (A16884, MM4550, MM13902), *S. clavuligerus* (A16886B, clavulanic acid), *S. lactamdurans* (cephamycin C), *S. griseus* (cephamycin A, B), *S. hygroscopicus* (deacetoxy-cephalosporin C), *S. wadayamensis* (WS-3442-D), *S. chartreusis* (SF 1623), *S. heteromorphus* and *S. panayensis* (C2081X); *S. cinnamonensis, S. fimbriatus, S. halstedii, S. rochei* and *S. viridochromogenes* (cephamycins A, B); *S. cattleya* (thienamycin); and *S. olivaceus, S. flavovirens, S. flavus, S. fulvoviridis, S. argenteolus,* and *S. sioyaensis* (MM 4550 and MM 13902)..

Preferred host cells of restrictionless strains of *Streptomyces* taxa that produce polyether antibiotics and in which the present vectors are especially useful and are transformed, include restrictionless cells of, for example: *S. albus* (A204, A28695A and B, salinomycin), *S. hygroscopicus* (A218, emericid, DE3936), A120A, A28695A and B, etheromycin, dianemycin), *S. griseus* (grisorixin), *S. conglobatus* (ionomycin), *S. eurocidicus* var. *asterocidicus* (laidlomycin), *S. lasaliensis* (lasalocid), *S. ribosidificus* (lonomycin), *S. cacaoi* var. *asoensis* (lysocellin), *S. cinnamonensis* (monensin), *S. aureofaciens* (narasin), *S. gallinarius* (RP 30504), *S. longwoodensis* (lysocellin), *S. flaveolus* (CP38936), *S. mutabilis* (S-11743a), and *S. violaceoniger* (nigericin).

Preferred host cells of restrictionless strains of *Streptomyces* taxa that produce glycopeptide antibiotics and in which the present vectors are especially useful and are transformed, include restrictionless cells of, for example: *S. orientalis* and *S. haranomachiensis* (vancomycin); *S. candidus* (A-35512, avaparcin), and *S. eburosporeus* (LL-AM 374).

Preferred host cells of other *Streptomyces* restrictionless strains in which the present vectors are especially useful and can be transformed, include restrictionless cells of, for example: *S. granuloruber, S. roseosporus, S. lividans, S. espinosus,* and *S. azureus.*

In addition to the representative *Streptomyces* host cells described above, the present vectors are also useful and can be transfromed into *E. coli.* Thus, vectors of the present invention have wide application and are useful and can be transformed into host cells of a variety of organisms.

While all the embodiments of the present invention are useful, some of the present recombinant DNA cloning vectors and transformants are preferred. Accordingly, preferred vectors are pJL114, pJL121, pJL125, pJL180, pJL190, pJL192, pJL195, pJL197, pJL199 and pHJL212 and preferred transformants are *Streptomyces griseofuscus*/pJL114, *S. griseofuscus*/pJL121, *S. griseofuscus*/pJL125, *S. griseofuscus*/pJL180, *S. griseofuscus*/pJL190, *S. griseofuscus*/pJL192, *S. griseofuscus*/pJL195, *S. griseofuscus*/pJL199, *S. griseofuscus*/pJL197, *S. griseofuscus*/pHJL212, *E. coli* K12 C600R_k-M_k-pJL114, *E. coli* K12 C600R_k-M_k-/pJL121, *E. coli* K12 C600R_k-M_k-/pJL125, *E. coli* K12 C600R_k-M_k-/pJL180, *E. coli* K12 C600R_k- M_k-/pJL190, *E. coli* K12 C600R_k-M_k-/pJL192, *E. coli* K12 C600R_k-M_k-/pJL195, *E. coli* K12 C600R_k-M_k-/pJL199, *E. coli* K12 C600R_k-M_k-/pJL197, and *E. coli* K12 C600R_k-M_k-/pHJL212. Moreover, of this preferred group, plasmids pJL190, pJL192, pJL195, pJL197, pJL199 and pJL , and transformants *S. griseofuscus*/pJL190, *S. griseofuscus*/pJL192, *S. griseofuscus*/pJL195, *S. griseofuscus*/pJL197, *S. griseofuscus*/pJL199, *S. griseofuscus*/pHJL212, *E. coli* K12 C600R_k-M_k-/pJL190, *E. coli* K12 C600R_k-M_k-/pJL192, *E. coli* K12 C600R_k-M_k-/pJL195 and *E. coli* K12 C600R_k-M_k-/pJL197, *E. coli* K12 C600R_k-M_k-/pJL199 and *E. coli* K12 C600R_k-M_k-/pHJL212 are most preferred. *Streptomyces griseofuscus* is a preferred host because it does not contain an endogenous plasmid or synthesize an antibiotic. Therefore, transformants of *S. griseofuscus* can be screened for clones that express genes for antibiotic synthesis.

The vectors of the present invention comprises origins of replication that are functional in *E. coli* and *Streptomyces* and therefore provide flexibility in the choice of hosts. Consequently, cloned DNA

sequences can be shuttled into *E. coli* for construction of new plasmids, physical analysis, and for mapping of restriction sites and then shuttled back into *Streptomyces* for functional analysis and improvement of strains. This is particularly advantageous because amplification and manipulation of plasmids can be done faster and more conveniently in *E. coli* than in *Streptomyces.* For example, the present vectors can be amplified conventionally in *E. coli* K12 by growth with spectinomycin or chloramphenicol. This is not possible in the *Streptomyces* host system. In addition, since all the plasmid vectors contain resistance markers that are expressed in *E. coli* K12, recombinants are easily selected. Therefore, large amounts of plasmid DNA can be isolated conveniently and in a shorter time than that required for doing similar procedures in *Streptomyces.* Thus, after desired recombinant DNA procedures are accomplished in the *E. coli* host system, the particular *Streptomyces* DNA can be removed, reconstructed to plasmid form (if necessary), and then transformed into a *Streptomyces* host cell. Since the present vectors are fully selectable in *Streptomyces,* identification of recombinant clones can be done efficiently.

The recombinant DNA cloning vectors and transformants of the present invention have broad utility and help fill the need for suitable cloning vehicles for use in *Streptomyces* and *E. coli.* Moreover, the ability of the present vectors to confer a pock phenotype or resistance to antibiotics also provides a functional means for selecting transformants. This is important because of the practical necessity for determining and selecting the particular cells that have acquired vector DNA. Additional DNA segments, that lack functional tests for their presence, can also be inserted into the present vectors and then transformants containing the non-selectable DNA can be isolated by appropriate antibiotic or other phenotype selection. Such non-selectable DNA segments can be inserted at any site, except within regions necessary for plasmid function and replication, and include genes that specify antibiotic modification enzymes and regulator genes of all types.

More particularly, a non-selectable DNA segment that comprises a gene can be inserted into a plasmid such as, for example, illustrative plasmid pJL192, at the internal *Bam*HI restriction site of the ~7.7 kb *Eco*RI-*Hind*III resistance-conferring fragment. Such an insertion inactivates the neomycin resistance gene and thus allows for the easy identification of *Streptomyces* transformants containing the recombinant plasmid. This is done by first selecting for M pock morphology and, secondarily, identifying those M transformants that are not resistant to neomycin. In a similar manner, insertion of a DNA segment into illustrative plasmid pJL180 at, for example, the unique *Pst*I restriction site, inactivates the ampicillin resistance gene. Thus, *E. coli* transformants carrying this recombinant plasmid can also be identified easily by first selecting for chloramphenicol resistance and, secondarily, identifying those chloramphenicol resistant transformants that are not resistant to ampicillin. Therefore, the ability to select for antibiotic resistance or other phenotypic markers in *Streptomyces* and *E. coli* allows for the efficient isolation of the extremely rare cells that contain the particular non-selectable DNA of interest.

The functional test for antibiotic resistance, as described above, can also be used to identify DNA segments that act as control elements and direct expression of an individual antibiotic resistance gene. Such segments, including but not limited to, promoters, attenuators, repressors, inducers, ribosomal binding sites, and the like, can be used to control the expression of other genes in cells of *Streptomyces* and *E. coli.*

The antibiotic resistance-conferring vectors of the present invention are also useful for insuring that linked DNA segments are stably maintained in host cells over many generations. These genes or DNA fragments, covalently linked to an antibiotic resistance-conferring fragment and propagated either in *Streptomyces* or *E. coli*, are maintained by exposing the transformants to levels of antibiotic that are toxic to non-transformed cells. Therefore, transformants that lose the vector, and consequently any covalently linked DNA, cannot grow and are eliminated from the culture. Thus, the vectors of the present invention can be used to maintain any DNA sequence of interest.

The cloning vectors and transformants of the present invention provide for the cloning of genes to improve yields of various products that are currently produced in *Streptomyces* and related cells. Examples of such products include, but are not limited to, Streptomycin, Tylosin, Cephalosporins, Actaplanin, Narasin, Monensin, Apramycin, Tobramycin, Erythromycin, and the like. The present invention also provides selectable vectors that are useful for cloning, characterizing, and reconstructing DNA sequences that code for commercially important proteins such as, for example, human insulin, human proinsulin, human growth hormone, bovine growth hormone, glucagon, interferon, and the like; for enzymatic functions in metabolic pathways leading to commercially important processes and compounds; or for control elements that improve gene expression. These desired DNA sequences include, but are not limited to, DNA that codes for enzymes that catalyze synthesis of derivatized antibiotics such as, for example, Streptomycin, Cephalosporin, Tylosin, Actaplanin, Narasin, Monensin, Apramycin, Tobramycin, and Erythromycin derivatives, or for enzymes that mediate and increase bioproduction of antibiotics or other products.

The capability of inserting, stabilizing, and shuttling the aforementioned DNA segments into *Streptomyces* and *E. coli* allows for easy recombinant genetic manipulation for increasing the yield and availability of antibiotics that are produced by *Streptomyces.* In addition, since the plasmid SCP2 or SCP2* origin of replication codes for low copy number, almost any DNA sequence, including those that

are lethal when expressed from a high copy number plasmid, can be readily cloned into the present vectors and shuttled between *Streptomyces* and *E. coli.*

Streptomyces coelicolor A3(2) and *S. coelicolor* M110, as respective sources of plasmids SCP2 and SCP2*, can be cultured in a number of ways using any of several different media. Carbohydrate sources which are preferred in a culture medium include, for example, molasses, glucose, dextrin, and glycerol, and nitrogen sources include, for example, soy flour, amino acid mixtures, and peptones. Nutrient inorganic salts are also incorporated and include the customary salts capable of yielding sodium, potassium, ammonia, calcium, phosphate, chloride, sulfate, and like ions. As is necessary for the growth and development of other microorganisms, essential trace elements are also added. Such trace elements are commonly supplied as impurities incidental to the addition of other constituents of the medium.

Streptomyces coelicolor M110 and *S. coelicolor* A3(2) are grown under aerobic culture conditions over a relatively wide pH range of about 5 to 9 at temperatures ranging from about 15° to 40°C. For production of plasmids SCP2 and SCP2* at highest copy number, however, it is desirable to start with a culture medium at a pH of about 7.2 and maintain a culture temperature of about 30°C. Culturing *Streptomyces coelicolor* M110 and *S. coelicolor* A3(2) under the aforementioned conditions, results in a reservoir of cells from which plasmids SCP2 and SCP2* are respectively isolated conveniently by techniques well known in the art.

The following examples further illustrate and detail the invention disclosed herein. Both an explanation of and the actual procedures for constructing the invention are described where appropriate.

Example 1
Isolation of plasmid SCP2*
A. Culture of *Streptomyces coelicolor* M110

A vegetative inoculum of *Streptomyces coelicolor* M110 (NRRL 15041) was conventionally prepared by growing the strain under submerged aerobic conditions in 50 ml of sterilized trypticase soy broth* at 35 g/l in deionized water.

The trypticase soy broth inoculum was incubated for 48 hours at a temperature of 30°C. The 50 ml culture was then homogenized, transferred to 450 ml of sterilized YEMESG** medium, and then incubated for at least 40, but not more than 65 hours, at 30°C. The pH was not adjusted. After incubation, the *Streptomyces coelicolor* M110 cells were ready for harvest and subsequent isolation of plasmid DNA.

*Trypticase soy broth is obtained from Difco Laboratories, Detroit, Michigan.

**YEMESG comprises .3% yeast extract, .5% peptone, .3% malt extract, 1% dextrose, 34% sucrose, .1% $MgCl_2$, and .1% glycine.

B. Plasmid isolation

About 10 g (wet wgt) of *Streptomyces coelicolor* M110 cells were harvested by centrifugation (10 minutes, 4°C, 10,000 rpm) and then about 10 ml/g wet wgt cells of TES buffer (.01 M Tris(hydroxymethyl)aminoethane [tris], .001 M EDTA, 25% sucrose, pH 8) was added. The cells were vortexed into suspension followed by addition of 10 ml/g wet wgt cells of .25 M EDTA, pH 8 and then 5 ml/g wet wgt cells of lysozyme (10 mg/ml in TES). After the mixture was incubated at 37°C for about 15 minutes, about 1.5 ml/g wet wgt cells of 20% SDS (sodium lauryl sulfate (BDH Chemicals Ltd. Poole, England), was added. The resultant mixture was allowed to stand at room temperature for 30 minutes, and then 5 M NaCl was added to give a final concentration of 1 M NaCl. After standing again at room temperature (15 minutes), the mixture was placed on ice for 2 hours. The lysate was centrifuged (20 minutes, 4°C, 17,500 rpm) and the supernatant was pooled and mixed with .64 volumes of isopropyl alcohol. The DNA precipitate was collected by centrifugation (15 minutes, 4°C, 10,000 rpm). The precipitate was air dried and then resuspended in 1 ml/g wet wgt cells of TE buffer (.01 M Tris, .001 M EDTA). Centrifugation (20 hours, 20°C, 50,000 rpm) using cesium chloride gradients with propidium iodide was carried out to purify the plasmid DNA. Following centrifugation, the desired plasmid SCP2* DNA band was removed and the propidium iodide extracted by conventional procedures. The CsCl-DNA solution was stored at —20°C. Prior to use, the DNA was desalted by either PD10 (Bio Rad) column exchange with TE or by dialysis against TE. The DNA was precipitated with ethanol by conventional procedures and redissolved in TE.

Example 2
Construction of plasmid pLR1
A. *Hind*III digestion of plasmid pIJ2

About 20 μl (20 μg) of plasmid pIJ2 DNA, disclosed in Thompson *et al.*, 1980, Nature 286:525, 5 μl BSA (Bovine Serum albumin, 1 mg/ml), 19 μl water, 1 μl of *Hind*III (containing 3 New England Bio Labs units) restriction enzyme*, and 5 μl reaction mix** were incubated at 37°C for 2 hours. The reaction was terminated by the addition of about 50 μl of 4 M ammonium acetate and 200 μl of 95% ethanol.

The resultant DNA precipitate was washed twice in 70% ethanol, dried *in vacuo*, suspended in 20 μl of TE buffer, and frozen at −20°C for storage.

*Restriction and other enzymes can be obtained from the following sources:
New England Bio Labs., Inc.
32 Tozer Road
Beverly, Massachusetts 01915
Boehringer-Mannheim Biochemicals
7941 Castleway Drive
Indianapolis, Indiana 46250
Bethesda Research Laboratories (BRL)
Box 6010
Rockville, Maryland 20850
Research Products
Miles Laboraties, Inc.
Elkhart, Indiana 46515

**Reaction mix for *Hind*III restriction enzyme was prepared with the following composition:
600 mM NaCl
100 mM Tris-HCl, pH 7.9
70 mM $MgCl_2$
10 mM Dithiothreitol

B. *Hind*III digestion of plasmid pBR322

About 8 μl (4 μg) of plasmid pBR322 DNA, 5 μl reaction mix, 5 μl BSA (1 mg/ml), 31 μl water, and 1 μl of *Hind*III restriction enzyme were incubated at 37°C for 2 hours. After the reaction was terminated by incubating at 60°C for 10 minutes, about 50 μl of ammonium acetate and 200 μl of 95% ethanol were added. The resultant DNA precipitate was washed twice in 70% ethanol, dried *in vacuo*, and suspended in 45 μl of water.

C. Ligation of *Hind*III digested plasmids pIJ2 and pBR322

About 20 μl of *Hind*III treated plasmid pIJ2 (from Example 2A), 20 μl of *Hind*III treated plasmid pBR322 (from Example 2B), 5 μl BSA (1 mg/ml), 1 μl of T4 DNA ligase*, and 5 μl ligation mix** were incubated at 16°C for 4 hours. The reaction was terminated by the addition of about 50 μl 4 M ammonium acetate and 200 μl of 95% ethanol. The resultant DNA precipitate was washed twice in 70% ethanol, dried *in vacuo*, and suspended in TE buffer. The suspended DNA constituted the desired plasmid pLR1.

*T4 DNA ligase can be obtained from the following source:
New England Bio Labs., Inc.
32 Tozer Rd.
Beverly, Massachusetts 01915

**Ligation mix was prepared with the following composition:
500 mM Tris-HCl, pH 7.8
200 mM Dithiothreitol
100 mM $MgCl_2$
10 mM ATP

Example

Construction of *E. coli* K12 HB101/pLR1

About 10 ml of frozen competent *E. coli* K12 HB101 cells (Bolivar *et al.*, 1977, Gene 2:75—93) were pelleted by centrifugation and then suspended in about 10 ml of .01 M sodium chloride. Next, the cells were pelleted again, resuspended in about 10 ml of .03 M calcium chloride, incubated on ice for 20 minutes, pelleted a third time, and finally, resuspended in 1.25 ml of .03 M calcium chloride. The resultant cell suspension was competent for subsequent transformation.

Plasmid pLR in TE buffer (prepared in Example 2C) was ethanol precipitated, suspended in 150 μl of 30 mM calcium chloride solution, and gently mixed in a test tube with about 200 μl of competent *E. coli* K12 HB101 cells. The resultant mixture was incubated on ice for about 45 minutes and then at 42°C for about 1 minute. Next, about 3 ml of L-broth (Bertani, 1951, J. Bacteriology 62:293) containing 50 μg/ml of ampicillin was added. The mixture was incubated with shaking at 37°C for 1 hour and then plated on L-agar (Miller, 1972, Experiments in Molecular Genetics, Cold Spring Harbor Labs, Cold Spring Harbor, New York) containing ampicillin. Surviving colonies were selected and tested for the expected phenotype (Amp^R, Tet^S), and constituted the desired *E. coli* K12 HB101/pLR1 transformants.

Example 4
Construction of plasmid pLR4
A. Partial *Bam*HI digestion of plasmid pLR1

About 10 μl (10 μg) of plasmid pLR1, 5 μl BSA (1 mg/ml), 29 μl water, 1 μl of *Bam*HI (diluted 1:4 with water) restriction enzyme, and 5 μl reaction mix* were incubated at 37°C for 15 minutes. The reaction was terminated by the addition of about 50 μl of 4 M ammonium acetate and 200 μl of 95% ethanol. The resultant DNA precipitate was washed twice in 70% ethanol, dried *in vacuo*, and suspended in 20 μl water.

*Reaction mix for *Bam*HI restriction enzyme was prepared with the following composition:
1.5 M NaCl
60 mM Tris-HCl, pH 7.9
60 mM $MgCl_2$

B. *Bam*HI digestion of plasmid pBR322

The desired digestion was carried out in substantial accordance with the teaching of Example 2B except that *Bam*HI restriction enzyme and reaction mix were used in place of *Hind*III restriction enzyme and reaction mix. The digested plasmid pBR322 was suspended in 29 μl of water.

C. Ligation of partial *Bam*HI digested plasmid pLR1 and *Bam*HI digested plasmid pBR322

The desired ligation was carried out in substantial accordance with the teaching of Example 2C. The resultant ligated DNA was suspended in TE buffer and constituted the desired plasmid pLR4.

Example 5
Construction of *E. coli* K12 HB101/pLR4

The desired construction was carried out in substantial accordance with the teaching of Example 3 except that plasmid pLR4, rather than plasmid pLR1, was used for transformation. Surviving colonies were selected and tested for the expected phenotype (Amp^R, Tet^S), and constituted the desired *E. coli* K12 HB101/pLR4 transformants.

Example 6
Construction of plasmids pJL120 and pJL121
A. *Eco*RI digestion of plasmid SCP2*

About 150 μl (5.7 μg) of plasmid SCP2* DNA, 1 ml water, 2 μl of *Eco*RI (containing 20 BRL units) restriction enzyme, and 17 μl *Eco*RI reaction mix* were incubated at 37°C for 2.5 hours. The reaction was terminated by incubation at 65°C for 15 minutes. The reaction was conventionally analyzed by agarose gel electrophoresis (AGE) to verify that restriction was complete. The restricted DNA was stored at 4°C for subsequent use.

*Reaction mix for *Eco*RI restriction enzyme was prepared with the following composition:
500 mM NaCl
1000 mM Tris-HCl, pH 7.5
100 mM $MgCl_2$

B. *Eco*RI digestion of plasmid pBR325

The desired digestion was carried out in substantial accordance with the teaching of Example 6A except that plasmid pBR325, rather than plasmid SCP2*, was used. The resultant DNA was stored at 4°C for subsequent use.

C. Ligation of *Eco*RI digested plasmids SCP2* and pBR325

About 40 μl of *Eco*RI digested plasmid SCP2* (from Example 6A), 10 μl of *Eco*RI digested plasmid pBR325 (from Example 6B), 10 μl of $MgCl_2$ (.1 M), 10 μl of $(NH_4)_2SO_4$ (.1 M), 10 μl ATP (2 mM) .1 μl of T4 DNA ligase, and 20 μl ligation mix* were incubated at 4°C for 18 hours. The reaction was analyzed by AGE to verify appropriate ligation. The suspended DNA constituted the desired ~35.8 kb plasmids pJL120 and pJL121.

Recombinant plasmids of two orientations result because the plasmid pBR325 *Eco*RI fragment can be oriented in either direction. A restriction site map of each of plasmids pJL120 and pJL121 was determined (after isolation as disclosed in Example 7) and is presented in Figure 2 of the accompanying drawings.

*Ligation mix was prepared with the following composition:
50 mM Tris-HCl, pH 7.5
10 mM β-mercaptoethanol
1 mM EDTA
50 mg/ml BSA

Example 7
Construction of *E. coli* K12 C600R_k-M_k-/pJL120 and *E. coli* K12 C600R_k-M_k-/pJL121
A. Preparation of frozen competent *E. coli* K12 C600R_k-M_k-

Fresh overnight cultures of *E. coli* K12 C600R_k-M_k- (disclosed in Chang and Cohen, 1974, Proc. Nat. Acad. Sci. 71:1030—1034) were subcultured 1:10 in fresh L-broth (disclosed in Miller, 1972, Experiments in Molecular Genetics, Cold Spring Harbor Labs., Cold Spring Harbor, New York) and grown at 37°C for 1 hour. A total of 660 Klett Units of cells were harvested, washed with 2.5 ml of 100 mM $NaCl_2$, suspended in 150 mM $CaCl_2$ with 10% glycerol, and incubated at room temperature for 20 minutes. The cells were harvested by centrifugation, resuspended in .5 ml of $CaCl_2$-glycerol, chilled on ice for 3—5 minutes and frozen. The suspensions of cells were stored in liquid nitrogen until use. Preservation and storage did not adversely affect the viability or frequency of transformation by covalently closed circular DNA.

B. Transformation

The competent cells were thawed in an ice bath and mixed in a ratio of .1 ml of cells to .05 ml of DNA (10 μl of the sample disclosed in Example 6C and 40 μl of .1 XSSC (.015 M NaCl, .0015 M Sodium Citrate at pH 7). The transformation mixture was chilled on ice for 20 minutes, heat shocked at 42°C for 1 minute and chilled on ice for 10 minutes. The samples were then diluted with .85 ml of L-broth, incubated at 37°C for 1.5 hours, spread on L-agar containing ampicillin (50 μg/ml) and tetracycline (12.5 μg/ml) and incubated for 18 hours at 37°C. The resultant colonies were selected and tested for the expected phenotype (Amp^R, Tet^R, CM^S), and constituted the desired *E. coli* K12 C600R_k-M_k-/pJL120 and *E. coli* K12 C600R_k-M_k-/pJL121 transformants. The ampicillin and tetracycline resistant colonies were isolated according to known procedures, cultured, and then conventionally identified by restriction enzyme and AGE analysis of the constitutive plasmids. The identified transformants were then used for subsequent production and isolation of plasmids pJL120 and pJL121 according to known procedures.

Example 8
Construction of plasmids pJL180 and pJL181
A. *Sal*I digestion of plasmid SCP2* and isolation of ~6.0 kb *Sal*I fragment

The desired digestion was carried out in substantial accordance with the teaching of Example 6 except *Sal*I restriction enzyme and reaction mix*, rather than *Eco*RI restriction enzyme and reaction mix, were used. The reaction was assayed by AGE to verify completion and terminated by heating at 65°C for 15 minutes. The resultant *Sal*I restriction fragments were separated by AGE and then the separated fragments were located in the gel by staining with ethidium bromide and visualizing fluorescent bands with an ultraviolet light. The gel fragment containing the ~6.0 kb fragment of interest was excised from the gel and electroeluted into TBE buffer (1.6% Sigma 7—9 buffer**, .093% Na_2EDTA, .55% boric acid). The gel-fragment in TBE buffer was placed in a dialysis bag and subjected to electrophoresis at 100 v for 1 hour. The aqueous solution was collected from the dialysis bag and passed over a DEAE cellulose column*** (.5 ml Whatman DE52) that had been equilibrated with equilibration buffer (.1 M KCl, 10 mM Tris-HCl, pH 7.8). The column was washed with 2.5 ml of equilibration buffer and the DNA (about 5 μg) was eluted with 1.5 ml of elution buffer (1 M NaCl, 10 mM Tris-HCl, pH 7.8). The eluent was adjusted to about .35 M with respect to Na^+ ion concentration, and then the DNA was precipitated by adding 2 volumes (about 9 ml) of 100% ethanol followed by cooling to —20°C for 16 hours. The DNA precipitate was pelleted by centrifugation, washed with 75% ethanol, dried, and dissolved in TE buffer. Hereinafter, this conventional isolation technique is referred to as AGE/DE52/electroelution.

*Reaction mix for *Sal*I restriction enzyme was prepared with the following composition:
1500 mM NaCl
80 mM Tris-HCl, pH 7.5
60 mM $MgCl_2$
2 mM EDTA

**Sigma 7—9 buffer can be obtained from Sigma Chemical Company, P.O. Box 14508, St. Louis, Missouri 63178.

***DEAE cellulose (DE52) can be obtained from Whatman Inc., 9 Bridewell Place, Clifton, New Jersey 07014.

B. *Sal*I digestion of plasmid pBR325

The desired digestion was carried out in substantial accordance with the teaching of Example 8A except that plasmid pBR325 was employed and fragments were not separated by preparative AGE/DE52/electroelution. The resultant DNA was dissolved in TE buffer and stored at 4°C for future use.

C. Ligation of *Sal*I digested plasmid pBR325 and ~6.0 kb *Sal*I fragment of plasmid SCP2*

About 1.5 μg of the 6.0 kb *Sal*I fragment of SCP2*, prepared in Example 8A, was mixed with .5 μg of *Sal*I digested pBR325, prepared in Example 8B. The DNA mixture was precipitated by standard ethanol precipitation and redissolved in 3 μl of distilled water, 4 μl of .66 M ATP, 2 μl of ligase-kinase mixture (.25 M Tris · HCl, pH 7.8, 50 mM $MgCl_2$, 25 mM dithiothreitol and 25% glycerol) and 1 μl of T4-DNA ligase (1 unit). After incubation for 1 hour at 15°C, the reaction mixture was diluted with 12 μl of water, 20 μl of .66 M ATP, 8 μl of ligase-kinase mixture and then incubated at 15°C for 18 hours. The resultant ligated DNA was diluted 1:5 into .1 XSSC and constituted the desired ~12.0 kb plasmids pJL180 and pJL181.

Recombinant plasmids of two orientations result because the plasmid pBR325 *Sal*I fragment can be oriented in either direction. A restriction site map of each of plasmids pJL180 and pJL181 is presented in Figure 3 of the accompanying drawings.

Example 9

Construction of *E. coli* K12 C600R_k-M_k-/pJL180 and *E. coli* K12 C600R_k-M_k-/pJL181

The desired constructions were made in substantial accordance with the teaching of Example 7 except that the mixture of plasmid pJL180 and pJL181 DNA (from Example 8C), rather than plasmid pJL120 and pJL121, were used. The resultant transformant colonies were selected and tested for the expected phenotype (Amp^R, Tet^S, CM^R), and constituted the desired *E. coli* K12 C600R_k-M_k-/pJL180 and *E. coli* K12 C600R_k-M_k-/pJL181 transformants. The ampicillin and chloramphenicol resistant colonies were isolated according to known procedures, cultured, and then conventionally identified by restriction enzyme and AGE analysis of the constitutive plasmids. The identified transformants can then be used for subsequent production and isolation of plasmids pJL180 and pJL181 according to known procedures.

Example 10

Construction of plasmid pJL125

A. *Sal*I digestion of plasmid pJL121 and isolation of ~10.2 kb *Sal*I fragment

The desired digestion was carried out in substantial accordance with the teaching of Example 8 except that the reaction was stopped before digestion was complete and except that plasmid pJL121, rather than plasmid SCP2*, was used. The resultant *Sal*I restriction fragments were not separated by preparative AGE but precipitated by standard ethanol precipitation. The restriction fragments were dissolved in TE buffer and immediately ligated.

B. Ligation of ~10.2 kb *Sal*I fragment of plasmid pJL121

The desired ligation was carried out in substantial accordance with the teaching of Example 8C except that the *Sal*I fragments of plasmid pJL121, rather than the *Sal*I fragment of plasmid SCP2* and pBR325, were used. The resultant ligated DNA constituted the desired plasmid pJL125 plus 12 other plasmids that were subsequently isolated and shown to contain additional *Sal*I restriction fragments of pJL121. Plasmid pJL125, which was conventionally isolated and contains an origin of replication from plasmid pBR325 and also the ~5.4 kb origin of replication-containing *Eco*RI-*Sal*I fragment of plasmid SCP2*, was dissolved in TE buffer and stored at 4°C for future use. A restriction site map of plasmid pJL125 is presented in Figure 4 of the accompanying drawing. The restriction site map was determined with plasmid from transformed *E. coli* K12 C600R_k-M_k-.

Example 11

Construction of *E. coli* K12 C600R_k-M_k-/pJL125

The desired construction was made in substantial accordance with the teaching of Example 7 except that plasmid pJL125, rather than plasmids pJL120 and pJL121, was used. The resultant colonies were selected and tested for the expected phenotype (Amp^R, Tet^S, CM^S) and constituted the desired *E. coli* K12 C600R_k-M_k-/pJL125 transformants. The identity of the transformants was further confirmed by AGE and restriction analysis by the procedure of Eckardt, 1978, Plasmid 1:584 and by Klein *et al.*, 1980, Plasmid 3:88. The transformants were then conventionally cultured for subsequent production and isolation of plasmid pJL125 according to known procedures.

Example 12

Construction of plasmid pJL190

A. *Eco*RI-*Hind*III digestion of plasmid pJL121 and isolation of ~19.0 kb *Eco*RI-*Hind*III fragment

About 200 μl (80 μg) of plasmid pJL121 DNA, 30 μl BSA (1 mg/ml), 40 μl of *Hind*III (containing 200 BRL units) restriction enzyme, and 30 μl *Hind*III reaction mix* were incubated at 37°C for about 3 hours and then at 65°C for 10 minutes. The 300 μl reaction mixture was cooled to 4°C, supplemented with 110 μl of 10× *Hind*III→*Eco*RI diluent reaction mix** and 30 μl *Eco*RI restriction enzyme (containing 300 BRL units), and then incubated at 37°C for 3 hours, then at 65°C for 10 minutes followed by cooling to 4°C. The resultant ~19.0 kb *Eco*RI-*Hind*III restriction fragment was

conventionally isolated by AGE/DE52/electroelution. The desired DNA was dissolved in TE buffer and stored at 4°C for future use.

*_Hind_III reaction mix was prepared with the following composition:
60 mM Tris-HCl, pH 7.5
500 mM NaCl
60 mM $MgCl_2$
**_Hind_III→_Eco_RI diluent was prepared with the following composition:
382 mM Tris-HCl, pH 7.5
50 mM NaCl
22 mM $MgCl_2$

B. _Eco_RI-_Hind_III digestion of plasmid pLR4 and isolation of ~7.7 kb _Eco_RI-_Hind_III fragment

The desired digestion and isolation was carried out in substantial accordance with the teaching of Example 12A except that plasmid pLR4, rather than plasmid pJL121, was used. The desired ~7.7 kb fragment was dissolved in TE buffer and stored at 4°C for future use.

C. Ligation of ~19.0 kb _Eco_RI-_Hind_III fragment of plasmid pJL121 and ~7.7 kb _Eco_RI-_Hind_III fragment of plasmid pLR4

The desired ligation was carried out in substantial accordance with the teaching of Example 8C except that the ~19.0 kb _Eco_RI-_Hind_III fragment of plasmid pJL121 and the ~7.7 _Eco_RI-_Hind_III fragment of plasmid pLR4, rather than the 6.0 kb _Sal_I fragment of plasmid SCP2* and _Sal_I digested pBR325, were used. The resultant ligated DNA constituted the desired plasmid pJL190 which was then stored at 4°C for future use. A restriction site and functional map of plasmid pJL190 is presented in Figure 4 of the accompanying drawings. The restriction site map was determined from plasmid transformed into _E. coli_ K12 C600R_k-M_k-.

Example 13

Construction of _E. coli_ K12 C600R_k-M_k-/pJL190

The desired construction was made in substantial accordance with the teaching of Example 7 except that plasmid pJL190, rather than plasmids pJL120 and pJL121, was used. The resultant colonies were selected and tested for the expected phenotype (Amp^R, Tet^S) and size by conventional means (as in Example 11) and constituted the desired _E. coli_ K12 C600R_k-M_k-/pJL190 transformants. The transformants were then conventionally cultured for subsequent production and isolation of plasmid pJL190 according to known procedures.

Example 14

Isolation of plasmid pJL192

Plasmid pJL192, which confers high resistance to antibiotic neomycin (10 μg/ml), can be conventionally isolated from _E. coli_ K12 C600R_k-M_k-/pJL192, a strain deposited and made part of the permanent stock culture collection of the Northern Regional Research Laboratory, Peoria, Illinois under the accession number 15040. The restriction site map of plasmid pJL192 appears not to be distinguishable from the plasmid pJL190 map presented in Figure 4.

Example 15

Construction of plasmid pJL195

A. _Eco_RI-_Sal_I digestion of plasmid pJL125 and isolation of ~5.4 kb _Eco_RI-_Sal_I fragment

The desired digestion and isolation was carried out in substantial accordance with the teaching of Example 12A except that plasmid pJL125 and _Sal_I restriction enzyme and reaction mix, rather than plasmid pJL121 and _Hind_III restriction enzyme and reaction mix, were used. In addition, _Sal_I→_Eco_RI diluent* was used. The resultant ~5.4 kb _Eco_RI-_Sal_I fragment was dissolved in TE buffer and stored at 4°C for future use.

*_Sal_I→_Eco_RI diluent was prepared with the following composition:
940 mM Tris-HCl, pH 7.5
55 mM $MgCl_2$

B. _Eco_RI-partial _Sal_I digestion of plasmid pLR4 and isolation of ~7.5 kb _Eco_RI-partial _Sal_I fragment

The _Sal_I digestion was carried out in substantial accordance with the teaching of Example 12A except plasmid pLR4, rather than pJL121, was used. Since only a partial _Sal_I digestion was desired, the resultant mixture was incubated first at 37°C for 15 minutes and then at 65°C for 10 minutes. Following cooling to 4°C, the resultant partial _Sal_I ~7.7 kb linear fragment was conventionally isolated by AGE/DE52/electroelution. The desired DNA was dissolved in TE buffer and digested with _Eco_RI restriction enzyme in substantial accordance with the teaching of Example 6A except that the above

fragment, rather than the *Sal*I fragment of SCP2*, was used. The desired ~7.5 kb *Eco*RI-*Sal*I fragment (the largest possible *Eco*RI-*Sal*I fragment) was isolated by AGE/DE52/electroelution, dissolved in TE buffer, and then stored at 4°C for future use.

C. Ligation of ~5.4 kb *Eco*RI-*Sal*I fragment of plasmid pJL125 and ~7.5 kb *Eco*RI-partial *Sal*I fragment of plasmid pLR4

The desired ligation was carried out in substantial accordance with the teaching of Example 8C except that the ~5.4 kb *Eco*RI-*Sal*I fragment of plasmid pJL125 and the ~7.5 kb *Eco*RI-partial *Sal*I fragment of plasmid pLR4, rather than the ~6.0 kb *Sal*I fragment of plasmid SCP2* and *Sal*I digested pBR325, were used. The resultant ligated DNA constituted the desired plasmid pJL195 and was stored at 4°C for future use. A restriction site map of plasmid pJL195 is presented in Figure 5 of the accompanying drawings. The restriction site map was determined with plasmid isolation from *E. coli* K12 C600R_k-M_k-.

Example 16
Construction of *E. coli* K12 C600R_k-M_k-/pJL195

The desired construction was made in substantial accordance with the teaching of Example 7 except that plasmid pJL195, rather than plasmids pJL120 and pJL121, was used. The resultant colonies were tested for the expected phenotype (Amp^R, Tet^S) and size (as in Example 11) and constituted the desired *E. coli* K12 C600R_k-M_k-/pJL195 transformants. The transformants were then conventionally cultured for subsequent production and isolation of plasmid pJL195 according to known procedures.

Example 17
Construction of plasmid pJL114
A. Partial *Bam*HI digestion of plasmid SCP2

The desired digestion was carried out in substantial accordance with the teaching of Example 6A except that plasmid SCP2 (isolated, in accordance with the teaching of Example 1, from *Streptomyces coelicolor* A3(2), a strain deposited and made part of the permanent stock culture collection of the Northern Regional Research Laboratory under the accession number 15042), and *Bam*HI restriction enzyme and reaction mix*, rather than plasmid SCP2* and *Eco*RI restriction enzyme and reaction mix, were used. The desired DNA was stored at 4°C for subsequent use.

*Reaction mix for *Bam*HI restriction enzyme was prepared with the following composition:
1000 mM Tris-HCl, pH 7.4
100 mM $MgCl_2$

B. Ligation of *Bam*HI digested plasmid SCP2 and *Bam*HI digested plasmid pBR322

The desired ligation was carried put in substantial accordance with the teaching of Example 6C except that the *Bam*HI digest of plasmid SCP2 (prepared in Example 17A) and *Bam*HI-digested plasmid pBR322 (prepared in Example 4B), rather than plasmids SCP2* and pBR325, were used. The resultant DNA was stored at 4°C and constituted the desired ~34.6 kb plasmid pJL114.

Example 18
Construction of *E. coli* K12 C600R_k-M_k-/pJL114

The desired construction as made in substantial accordance with the teaching of Example 7 except that plasmid pJL114, rather than plasmids pJL120 and pJL121, was used. The resultant colonies were selected and tested for the expected phenotype (Amp^R, Tet^S), and constituted the desired *E. coli* K12 C600R_k-M_k-/pJL114 transformants. The ampicillin resistant, tetracycline sensitive colonies were isolated according to known procedures, cultured, and then conventionally identified by restriction enzyme and agarose gel electrophoretic analysis of the constitutive plasmids.

It was revealed upon analysis that the *Bam*HI restriction enzyme had cut only one of the *Bgl*II restriction sites of SCP2 during the digestion described in Example 17A. Since this event is rare and has not been repeated, *E. coli* K12 C600R_k-M_k-/pJL114 has been deposited and made part of the permanent stock culture collection of the Northern Regional Research Laboratory, Peoria, Illinois under the accession number B-15039. The strain is available as a preferred source and stock reservoir of plasmid pJL114. A restriction site map of plasmid pJL114 is presented in Figure 5 of the accompanying drawings.

Example 19
Construction of *Streptomyces griseofuscus*/pJL120
A. Growth of cultures for preparation of protoplasts

A vegetive innoculum was conventionally prepared by growing the strain under submerged conditions for 20 hours at 30°C in TSB supplemented with .4% glycine. The culture was homogenized and innoculated at a 1/20 dilution into the same medium and then grown for 18 hours at 30°C.

B. Transformation

Using about 20 μg of plasmid pJL120 DNA and 1×10^9 protoplasts of *Streptomyces griseofuscus*, a strain deposited and made part of the permanent stock culture collection of the American Type Culture Collection, Rockville, Maryland, from which it is available to the public under the accession number ATCC 23916, the desired transformation was carried out in substantial accordance with the teaching of International Publication (of International Patent Application No. PCT/BG79/00095) No. W079/01169, Example 2.

C. Selection

To assay for transformation even at low frequencies, two procedures were employed.

(1) Pock-assay:

Spores were harvested from the regeneration plates containing confluent lawns of regenerated protoplasts as follows. About 10 ml of sterile distilled water was added to the plate and the surface of the culture gently scraped with a loop to remove the spores. The resulting spore suspension was centrifuged at 20,000 rpm for 10 minutes. The supernatant was discarded and the remaining spore pellet resuspended in .3 ml of 20% v/v glycerol. Serial dilutions of the preparation were made down to 10^{-5} by successive transfer of .1 ml of the spore suspension to .9 ml of 20% v/v glycerol. The spores can then be stored at −20°C with little loss of viability. About .1 ml aliquots of some of the dilution series (e.g. 10^{-1}, 10^{-2}, 10^{-4}) of each of the harvested plates were then transferred to R_2 medium (Hopwood and Wright, 1978, Molecular and General Genetics 162:30) plates which had sufficient spores of the *Streptomyces griseofuscus* strain originally used in the transformation procedure to produce a confluent lawn. This procedure can also be carried out with the substitution of YMX agar (.5% yeast extract, .5% malt extract, .1% dextrose and 2% agar). Transformants can typically be detected after 3 days' growth at 30°C by the appearance of "pocks", a property expressed by spores containing the plasmid in expressible form within the lawn. The transformants were recovered by conventionally picking spores from the centre of the "pock" to an agar plate of YMX medium (Hopwood 1967. Bacteriological Review, 31:373).

(2) Back transformation to *E. coli* K12 C600R_k-M_k-:

The spores are collected as in (1) above but are used to innoculate 50 ml of TSB supplemented with .4% glycine. The culture is grown for 20 hours at 30°C and the cells are harvested followed by isolation of DNA. Isolation is as disclosed in Example 1B except that centrifugation with CsCl and propidium iodide is omitted. Subsequently, 50 μl of this DNA is used to transform *E. coli* K12 C600R_k-M_k- as disclosed in Example 7B. Plasmids in the transformants are verified and identified by conventional means as taught in Example 11.

Example 20

Construction of *Streptomyces griseofuscus*/pJL114, *S. griseofuscus*/JL121, *S. griseofuscus*/pJL125, *S. griseofuscus*/pJL180, and *S. griseofuscus*/pJL181

The desired constructions were each individually and respectively made, selected, and recovered in substantial accordance with the teaching of Example 20 except that plasmids pJL114, pJL121, pJL125, pJL180, and pJL181, rather than plasmid pJL120, were appropriately used for the individual construction.

Example 21

Construction of *Streptomyces griseofuscus*/pJL190

A. Transformation

The desired transformation was carried out in substantial accordance with the teaching of Example 19B except that plasmid pJL190, rather than plasmid pJL120, was used.

B. Selection

The desired transformants were selected for neomycin resistance by overlaying the regenerating protoplasts with R_2 medium top agar containing sufficient neomycin to bring the final plate concentration to 1 μg/ml. The resultant *Streptomyces griseofuscus*/pJL190 transformants were then tested for the expected pock morphology in substantial accordance with the procedure of Example 20B.

Example 22

Construction of *Streptomyces griseofuscus*/pJL195

The desired construction was made, selected, and recovered in substantial accordance with the teaching of Example 21 except that plasmid pJL195, rather than plasmid pJL190, was used.

Example 23

Construction of *Streptomyces griseofuscus*/pJL192

The desired construction was made, selected, and recovered in substantial accordance with the teaching of Example 22 except that plasmid pJL192 and, in the selection procedure, top agar containing sufficient neomycin to bring the final plate concentration to 10 μg/ml, rather than plasmid pJL195 and top agar containing sufficient neomycin to bring the final plate concentration to 1 μg/ml, were used.

Example 24

Construction of *Streptomyces fradiae*/pJL120, *S. fradiae*/pJL114, *S. fradiae*/pJL121, *S. fradiae*/pJL125, *S. fradiae*/pJL180, *S. fradiae*/pJL181, *S. fradiae*/pJL190, *S. fradiae*/pJL195, and *S. fradiae*/pJL192

The desired constructions are individually and respectively made, selected, and recovered in substantial accordance with the respective teachings of Examples 19, 20, 21, 22, and 23 except that *Streptomyces fradiae*, rather than *S. griseofuscus*, is used. In addition, the TSB medium for protoplasting and growing *S. fradiae* was modified and contained only .2% glycine.

Example 25

Construction of *Streptomyces lividans*/pJL120, *S. lividans*/pJL114, *S. lividans*/pJL121, *S. lividans*/pJL125, *S. lividans*/pJL180, *S. lividans*/pJL181, *S. lividans*/pJL190, *S. lividans*/pJL195, and *S. lividans*/pJL192

The desired constructions are individually and respectively made, selected, and recovered in substantial accordance with the respective teachings of Examples 19, 20, 21, 22, and 23 except that *Streptomyces lividans*, rather than *S. griseofuscus*, is used. In addition, the media for protoplasting and growing *S. lividans* is as described in International Publication (of International Patent Application No. PCT/BG79/00095) No. W079/01169, Example 2.

Example 26

Isolation of plasmid pJL192 mutant that confers high resistance to antibiotic neomycin

Streptomyces griseofuscus/pJL190 was isolated as described in Example 21. Analysis of growth of colonies on nutrient agar supplemented with different concentrations of neomycin revealed that *S. griseofuscus*/pJL190 exhibited resistance to 1.0 μg/ml of neomycin. *S. griseofuscus* was spread conventionally on nutrient agar plates supplemented with 10 μg/ml of neomycin. A colony was discovered that exhibited growth at this high level of neomycin. After repeated analysis verified that the colony exhibited the aforementioned resistance, the colony was designated *S. griseofuscus*/pJL192. The polasmid, pJL192 was shuttled into *E. coli* K12 C600R_k-M_k- by back transformation as taught in Example 19C. The restriction site map of pJL192 appears not to be distinguishable from pJL190.

Example 27

Isolation of plasmid pJL199 mutant that confers high resistance to antibiotic neomycin

The desired isolation is carried out in substantial accordance with the teaching of Example 26 except that *Streptomyces griseofuscus*/pJL195 (prepared in Example 22), rather than *S. griseofuscus*/pJL190, was used. A colony that exhibited high resistance to neomycin was designated *S. griseofuscus*/pJL199. The plasmid, pJL199, was shuttled into *E. coli* K12 C600R_k-M_k- by back transformation as taught in Example 19C. The restriction site map of pJL199 appears not to be distinguishable from pJL195.

Those skilled in the art will recognize that plasmid pJL199 can also be conventionally constructed by substituting the neomycin resistance-conferring fragment of plasmid pJL192 (prepared in Examples 15 and 27) for the pLR4-derived neomycin resistance-conferring fragment of plasmid pJL195. Such a substitution thus also results in the desired plasmid pJL199.

Example 28

Construction of plasmid pLR2

A. *Hind*III digestion of plasmid pIJ6

About 20 μl (20 μg) of plasmid pIJ6 DNA, disclosed in Thompson *et al.*, 1980, Nature 286:525, 5 μl BSA (Bovine Serum albumin, 1 mg/ml), 19 μl water, 1 μl of *Hind*III (containing 3 New England Bio Labs units) restriction enzyme*, and 5 μl reaction mix** were incubated at 37°C for 2 hours. The reaction was terminated by the addition of about 50 μl of 4 M ammonium acetate and 200 μl of 95% ethanol. The resultant DNA precipitate was washed twice in 70% ethanol, dried *in vacuo*, suspended in 20 μl of TE buffer, and frozen at −20°C for storage.

B. *Hind*III digestion of plasmid pBR322

About 8 μl (4 μg) of plasmid pBR322 DNA, 5 μl reaction mix, 5 μl BSA (1 mg/ml), 31 μl water, and 1 μl of *Hind*III restriction enzyme were incubated at 37°C for 2 hours. After the reaction was terminated by incubating at 60°C for 10 minutes, about 50 μl of ammonium acetate and 200 μl of

95% ethanol were added. The resultant DNA precipitate was washed twice in 70% ethanol, dried *in vacuo*, and suspended in 45 μl of water.

C. Ligation of *Hind*III digested plasmids pIJ6 and pBR322

About 20 μl of *Hind*III treated plasmid pIJ6 (from Example 2A), 20 μl of *Hind*III treated plasmid pBR322 (from Example 2B), 5 μl BSA (1 mg/ml), 1 μl of T4 DNA ligase*, and 5 μl ligation mix** were incubated at 16°C for 4 hours. The reaction was terminated by the addition of about 50 μl 4 M ammonium acetate and 200 μl of 95% ethanol. The resultant DNA precipitate was washed twice in 70% ethanol, dried *in vacuo*, and suspended in TE buffer. The suspended DNA constituted the desired plasmid pLR2.

Example 29

Construction of *E. coli* K12 HB101/pLR2

About 10 ml of frozen competent *E. coli* K12 HB101 cells (Bolivar *et al.*, 1977, Gene 2:75—93) were pelleted by centrifugation and then suspended in about 10 ml of 0.01 M sodium chloride. Next, the cells were pelleted again, resuspended in about 10 ml of 0.03 M calcium chloride, incubated on ice for 20 minutes, pelleted a third time, and finally, resuspended in 1.25 ml of 0.03 M calcium chloride. The resultant cell suspension was competent for subsequent transformation.

Plasmid pLR2 in TE buffer (prepared in Example 2C) was ethanol precipitated, suspended in 150 μl of 30 mM calcium chloride solution, and gently mixed in a test tube with about 200 μl of competent *E. coli* K12 HB101 cells. The resultant mixture was incubated on ice for about 45 minutes and then at 42°C for about 1 minute. Next, about 3 ml of L-broth (Bertani, 1951, J. Bacteriology 62:293) containing 50 μg/ml of ampicillin was added. The mixture was incubated with shaking at 37°C for 1 hour and then plated on L-agar (Miller, 1972, Experiments in Molecular Genetics, Cold Spring Harbor Labs, Cold Spring Harbor, New York) containing ampicillin. Surviving colonies were selected and tested for the expected phenotype (Amp^R, Tet^S), and constituted the desired *E. coli* K12 HB101/pLR2 transformants.

Representative plasmids and transformants that can be constructed in accordance with the foregoing teaching include the following listed below in Tables 1 and 2.

Table 1
Representative plasmids

Example No.	*Plasmid name*	*~Size in kb*	*E. coli marker*	*Streptomyces marker*	*Construction*
30	pJL122	24.4	Amp^R, Tet^R	M	*Sst*I Deletion of pJL120
31	pJL123	27.8	Amp^R, Tet^R	M	*Bgl*II Deletion of pJL121
32	pJL124	21.1—24.2	Amp^R, Tet^R	M	Partial *Pst*I Deletion of pJL120
33	pJL126	9.1—10.6	Amp^R, Tet^R	M	Partial *Xor*II Deletion of pJL120
34	pJL176	32.5	CM^R, Tet^R	P*	~16.6 kb *Pst*I and extraveous ~10.0 kb *Pst*I of SCP2* into *Pst*I Site of pBR325
35	pJL1200	35.8	Amp^R, Tet^R	M	SCP2 *Eco*RI Site into pBR325 *Eco*RI Site
36	pJL1201	35.8	Amp^R, Tet^R	M	Reverse Orientation of pJL1200
37	pJL1202	24.4	Amp^R, Tet^R	M	*Sst*I Deletion of pJL1200
38	pJL1203	27.8	Amp^R, Tet^R	M	*Bgl*II Deletion of pJL1201
39	pJL1204	21.1—24.2	Amp^R, Tet^R	M	Partial *Pst*I Deletion of pJL1200
40	pJL1205	10.2	Amp^R	M	*Sal*I Deletion of pJL1201
41	pJL1206	9.1—10.6	Amp^R, Tet^R	M	Partial *Xor*II Deletion of pJL1200
42	pJL1706	32.5	CM^R, Tet^R	P	~10.6 kb *Pst*I and extraneous ~10.0 kb *Pst*I of SCP2 into *Pst*I Site of pBR325
43	pJL1716	22.5	CM^R, Tet^R	P	~16.6 *Pst*I of SCP2 into *Pst*I Site of pBR325
44	pJL3176	22.5	CM^R, Tet^R	P*	~16.6 *Pst*I of SCP2* into *Pst*I Site of pBR325
45	pJL1800	12.6	Amp^R, CM^R	P	~6.0 kb *Sal*I of SCP2 into *Sal*I Site of pBR325
46	pJL1801	12.6	Amp^R, CM^R	P	Reverse Orientation of pJL1800
47	pJL1900	25.9	Amp^R	M, Neo^R	~19.0 kb *Eco*RI-*Hind*III of pJL1201 and ~7.7 kb *Eco*RI-*Hind*III of pLR4

Table 1 (contd.)
Representative plasmids

Example No.	*Plasmid Name*	*~Size in kb*	*E. coli marker*	*Streptomyces marker*	*Construction*
48	pJL1902	25.9	Amp^R	M, Neo^R	~19.0 kb *Eco*RI-*Hind*III of pJL1201 and ~7.7 kb *Eco*RI-*Hind*III of pLR4
49	pJL1905	12.1	Amp^R	M, Neo^R	~5.4 kb *Eco*RI-*Sal*I of pJL1205 and ~7.5 kb *Eco*RI-Partial *Sal*I of pPR4
50	pJL193	6.9	Amp^R	$Thio^R$	~1.35 kb *Bam*HI of pLR 2 into *Bam*HI of pBR328
51	pJL196	12.1	Amp^R	M, Neo^R	~5.4 kb *Eco*RI-*Sal*I of pJL125 into ~7.5 kb *Eco*RI-partial *Sal*I of pJL192
52	pJL197	13.1	Amp^R	M, Neo^R, $Thio^R$	~ 1 kb *Bcl*I of pJL193 into partial *Bam*HI of pJL196, orientation such that the *Cla*I site of the ~1 kb *Bcl*I fragment is proximal to the *Sal*I site of the pBR322 fragment and such that the *Sal*I site of the ~1 kb *Bcl*I site is proximal to the neomycin resistance gene
53	pJL1907	13.1	Amp^R	M, Neo^R, $Thio^R$	~1 kb *Bcl*I of pJL193 into partial *Bam*HI of pJL1905
54	pJL198	13.1	Amp^R	M, Neo^R, $Thio^R$	Same as pJL197 except the orientation of the *Bcl*I fragment is reversed
55	pHJL212	13.9	Amp^R	M, Neo^R, $Thio^R$	~1 kb *Bcl*I fragment of pJL193 into partial *Bam*HI of pJL195, orientation and insertion the same as pJL198
56	pHJL213	13.9	Amp^R	M, Neo^R, $Thio^R$	Same as pHJL212 except the orientation and insertion the same as pJL197

Table 2
Representative transformants

1. *Streptomyces* R/pR[1] wherein R is *griseofuscus, ambofaciens, fradiae,* or *lividans* and R[1] is independently pJL122, pJL123, pJL124, pJL126, pJL176, pJL1200, pJL1201, pJL1202, pJL1203, pJL1204, pJL1205, pJL1206, pJL1706, pJL1800, pJL1801, pJL1900, pJL1902, pJL1905, pJL196, pJL197, pJL1907, pJL198, pHJL212 and pHJ213.

2. *E. coli* K12 R[2]/pR[1] wherein R[2] is C600R_k-M_k- 294, C600 or RV308 and R[1] is independently as defined above.

Claims

1. A recombinant DNA cloning vector comprising:

a) a functional origin of replication-containing restriction fragment of plasmid SCP2 or SCP2*,

b) a restriction fragment comprising an *E. coli* origin of replication,

c) one or more DNA segments that confer resistance to at least one antibiotic when transformed into a cell of *E. coli*, said cell being sensitive to the antibiotic for which resistance is conferred, and

d) one or more DNA segments that independently confer either or both of the *Streptomyces tra* function or resistance to at least one antibiotic when transformed into a cell of *Streptomyces*, said cell being sensitive to the antibiotic for which resistance is conferred.

2. The vector of Claim 1 which is a plasmid.

3. The vector of Claim 1 or 2, wherein the restriction fragment of plasmid SCP2 or SCP2* is the ~5.4 kb *Eco*RI-*Sal*I fragment, ~6.0 kb *Sal*I fragment, ~19 kb *Eco*RI-*Hind*III fragment, or ~31 kb *Eco*RI fragment.

4. The vector of Claim 1, 2 or 3, wherein the *E. coli* origin of replication is the pBR322 origin of replication, pBR324 origin of replication, pBR325 origin of replication, pBR327 origin of replication, or pBR328 origin of replication.

5. The vector of any of Claims 1 to 4, wherein the one or more DNA segments that confer resistance in *E. coli* are DNA segments that confer resistance to ampicillin, chloramphenicol or tetracycline.

6. The vector of any of Claims 1 to 5, wherein the one or more DNA segments that confer resistance in *Streptomyces* are DNA segments that confer resistance to neomycin or thiostrepton.

7. The vector of Claim 6 which is plasmid pJL180, pJL181, pJL125, pJL190, pJL192, pJL195, pJL199, pJL122, pJL123, pJL124, pJL126, pJL176, pJL1200, pJL1201, pJL1020, pJL1203, pJL1204, pJL1205, pJL1206, pJL1706, pJL1800, pJL1801, pJL1900, pJL1902, pJL1905, pJL193, pJL196, pJL197, pJL198, pHJL212, pHJL213, or pJL1907.

8. The vector of any of Claims 1 to 7, wherein the DNA segment that confers resistance to an antibiotic is the ~7.7 kb *Eco*RI-*Hind*III restriction fragment of plasmid pJL192, the ~7.7 kb *Eco*RI-*Hind*III restriction fragment of plasmid pLR4, the ~7.5 kb *Eco*RI-partial *Sal*I restriction fragment of plasmid pLR4, the ~1.35 kb *Bam*HI restriction fragment of plasmid pLR2, or the ~1 kb *Bcl*I restriction fragment of plasmid pJL193.

9. The vector of Claim 8 which is a plasmid pJL190 or pJL195 high resistance mutant that in *Streptomyces* confers resistance to neomycin at levels of at least 10 μg/ml.

10. Plasmid pJL114.

11. Plasmid pJL120.

12. Plasmid pJL121.

13. Plasmid pJL192.

14. Plasmid pJL193.

15. Plasmid pJL197.

16. Plasmid pJL198.

17. Plasmid pHJL212.

18. Plasmid pHJL213.

19. A transformed host cell comprising the recombinant DNA cloning vector of any of Claims 1 to 18.

20. The host cell of Claim 19 which is *Streptomyces*, preferably of species *lividans, griseofuscus, fradiae,* or *ambofaciens.*

21. The host cell of Claim 19 which is *E. coli* K12.

22. A restriction fragment comprising the plasmid SCP2 or SCP2* ~5.4 kb *Eco*RI-*Sal*I or ~6.0 kb *Sal*I restriction fragment of Claim 3.

23. A restriction fragment comprising the plasmid pJL192 ~7.7 kb *Eco*RI-*Hind*III restriction fragment of Claim 8.

24. A process for preparing a recombinant DNA cloning vector which comprises ligating a functional origin of replication-containing restriction fragment of plasmid SCP2 or SCP2* and one or more DNA sequences comprising:

a) a restriction fragment comprising an *E. coli* origin of replication,

b) one or more DNA segments that confer resistance to at least one antibiotic when transformed into a cell of *E. coli*, said cell being sensitive to the antibiotic for which resistance is conferred, and

c) one or more DNA segments that independently confer either or both of the *Streptomyces tra* function or resistance to at least one antibiotic when transformed into a cell of *Streptomyces,* said cell being sensitive to the antibiotic for which resistance is conferred.

25. The process of Claim 24, wherein the restriction fragment of plasmid SCP2 or SCP2* is the ~5.4 kb *Eco*RI-*Sal*I fragment, ~6.0 kb *Sal*I fragment, ~19 kb *Eco*RI-*Hind*III fragment, or ~31 kb *Eco*RI fragment and wherein the *E. coli* origin of replication is the pBR322 origin of replication, pBR324 origin of replication, pBR325 origin of replication, pBR327 origin of replication, or pBR328 origin of replication, and wherein the one or more DNA segments that confer resistance in *E. coli* are DNA segments that confer resistance to ampicillin, chloramphenicol or tetracycline and wherein the one or more DNA segments that confer resistance in *Streptomyces* are DNA segments that confer resistance to neomycin or thiostrepton.

26. A method for detecting transformants comprising:

1) mixing *Streptomyces* cells, under transforming conditions, with a recombinant DNA cloning vector, said vector comprising

a) an origin of replication and P gene-containing restriction fragment of plasmid SCP2 or SCP2*, and

b) a non-lethal DNA sequence cloned into the *Eco*RI restriction site of said P gene, and

2) growing said *Streptomyces* cells on a lawn of an indicator *Streptomyces* strain and selecting colonies that show the M pock phenotype.

27. The method of Claim 26, wherein the restriction fragment comprising the origin of replication and the P gene is of plasmid SCP2*.

28. The method of Claim 26 or 27, wherein the *Streptomyces* cells and indicator strain are preferably of species *lividans, griseofuscus, fradiae* or *ambofaciens.*

29. The method of Claim 26, 27 or 28, wherein the recombinant DNA cloning vector is plasmid pJL120, pJL121, pJL125, pJL190, pJL192, pJL195, pJL197, pJL198, pHJL212, or pHJL213.

30. A recombinant DNA cloning vector substantially as hereinbefore described with particular reference to Examples 8, 10, 12, 15, 26, 27 and 30 to 56.

31. A restriction fragment substantially as hereinbefore described with particular reference to Examples 8a and 12b.

32. A transformed host cell substantially as hereinbefore described with particular reference to Examples 9, 11, 13, 16, and 19 to 25, and Table 2.

33. A process for preparing a recombinant DNA cloning vector substantially as hereinbefore described with particular reference to Examples 8, 10, 12, 15, 26, 27 and 30 to 56.

34. A method for detecting transformants substantially as hereinbefore described with particular reference to Example 19C.

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